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EDWARD ORTON.

Edward Orton, born Deposit, Delaware county, N. Y., March 9, 1829, was descended from old New England stock on both sides of the house. His father, Thomas Orton, a Presbyterian clergyman, whose memory is still cherished in northwestern New York, moved to Ripley, N. Y., on the Lake Erie shore soon after his son's birth. There the son grew up amid an agricultural population, sharing their work and their amusements and gaining an intimate knowledge of their needs which affected his whole course in life. As a lad, he is said to have been somewhat shrinking and sensitive to ridicule; always courteous, always considerate of the feelings of others and sternly conscientious.

His father prepared him for college and, at what appears to us the early age of fifteen, he entered the Sophomore year at Hamilton with the class of 1848. The college course of fifty years ago was narrow, carefully avoiding more than very superficial treatment of the inductive sciences and dwelling chiefly upon classics, elementary mathematics and certain philosophical studies. Edward Orton pursued the course faithfully, though there was little in it attractive to one of his tastes, and at graduation he had a well trained mind with a good stock of such

knowledge as the course afforded. The careful drill in linguistics was that from which he derived most profit, and it was in evidence throughout his writings.

After teaching for one year at Erie, Pa., he entered Lane Theological Seminary at Cincinnati, O., to prepare for the Presbyterian ministry, but, before the year ended, his eyesight failed and he gave up study to become clerk on a coasting vessel sailing to Florida. The autumn of 1851 found him in the Delaware Literary Institute at Franklin, N. Y., where, as instructor in Natural Sciences and German, he was expected to teach any subject offered in the very liberal curriculum. The hours were long and the classes numerous, but his enthusiasm infected the pupils, who accompanied him on long field excursions for study of botany and geology. The next year was spent at Harvard in the study of chemistry and botany, after which another year was spent in successful teaching at Franklin. He then entered Andover Theological Seminary to complete preparation for the ministry. He was licensed in 1855. and soon afterward was ordained to act as pastor of the Presbyterian church at Downsville, Delaware county, N. Y.

He resigned his charge in June 1856, to become professor of Natural Sciences in the New York State Normal School at Albany, N. Y. There he had access to the State Museum and was associated intimately with the strong men on its staff. His life in the Normal School was ideal, and his studies in the State Museum were what he had longed for. Everything appeared to be conspiring to his benefit and to great usefulness in his chosen work.

But, early in his theological studies, doubts had arisen in his mind respecting some tenets of the church and these, it is believed, had something to do with the abrupt termination of his studies at Lane seminary. These doubts were made stronger by the surroundings at Harvard and he undertook the study at Andover with an earnest desire to remove them. It contributed to that result at least so far as to render them subordinate and to permit him to assume the Presbyterian ministry. After he

went to Albany, however, the doubts returned and, increasing in intensity, became convictions so strong that he could not consent to remain in connection with his denomination. To avow his opinions, which, being practically those of the Unitarian church, were very unpopular at that time, would involve not only separation from his church affiliations but also loss of his position in the Normal School; for, though that was a state institution, a public discussion of his views might have alienated an influential portion of the community if he had retained his chair. To many men the temptation would have been serious; no longer in the active ministry, he could have concealed his opinions and could have withdrawn from his denomination without discussion, in this way retaining his position, so important as affording not merely support but also opportunity for thorough study. But his sturdy integrity knew nothing of casuistry; he could not be guilty of even negative hypocrisy. He avowed his opinions, gave up his position, lost his income but gained the abiding respect of his associates, both in church and in school.

The only opening immediately available was the principalship of an academy at Chester, Orange county, N. Y., which he accepted and held for six years, fitting young men for college and lecturing on scientific subjects whenever he had opportunity. His duties left little of spare time, but what he had was utilized in study of such natural phenomena as the region presented, especially those connected with agricultural interests — an admirable preparation for his future work.

Professor Orton's intimate friend at Chester was the Rev. Austin Craig, pastor of an independent church near that place. In 1865, Mr. Craig was chosen acting president of Antioch College in Yellow Springs, O., and Professor Orton was made principal of the preparatory department. Soon afterwards he was appointed to the chair of Natural Sciences. He proved himself so wise, so tactful, that, in 1872, he was called to the presidency of the college. But he was reluctant to assume the responsibility and wrote to Dr. Newberry, with whom he was associated on the State Geological Survey, asking advice. In a

manly way, without self-depreciation, he gave his reasons for hesitation. Dr. Newberry's emphatic reply was that a man's friends usually understand him better than he does himself. The position was accepted and the event proved that his friends were right. His administration was marked with such vigor, and at the same time with such good judgment in dealing with men both inside and outside of the college that he soon became known throughout the state. When the State Agricultural College was organized in 1873, he was made president, and professor of geology.

The organization of a state college with the agricultural land grant as the endowment was a task whose magnitude might well appal a thoughtful man. Local colleges dreaded a powerful rival; farmers demanded a curriculum suited to their conception of agriculture; lovers of the old methods of education feared too much of application to everyday matters; "practical" men insisted that little attention should be paid to theory, and that "practice" should be supreme; politicians saw in the new institution an opportunity to strengthen themselves by grants of positions; while not a few thought the gift from the national government might prove to be another Pandora's box. But happily, the first board of trustees proved to be men of excellent common sense; they recognized that the work of organization, if it were to be done well, would have to be done by one familiar with educational needs, and that without interference. The work was left to President Orton, whose studies of agricultural conditions, carried on so assiduously for many years, supplemented by his work as teacher, professor, and college president, had rendered him familiar with the complex problems involved. The curriculum was planned, not with a view to bringing the greatest number of students at the earliest moment, but with a view to the advantage of the state and of higher education. The wisdom of this course was soon manifest, for, though the number of students was small during the first year, it increased so rapidly, and the scope of the institution was expanded so greatly that in 1878 the name was changed to the Ohio State

University, the older title being recognized as no longer applicable.

But executive duties were never attractive to him; they interfered with his work as a student. Again and again he asked to be relieved from the presidency, but not until 1881 did the trustees feel that the institution could bear a change. At that time, when the university was established and its policy determined, they yielded to his urgent request. Thenceforward he devoted himself to the chair of geology. With characteristic wisdom he became merely a professor, and apparently forgot that he had been president. One finds no room for surprise at the respect and affection with which his colleagues regarded him.

Professor Orton's love for natural science was distinct early in life, but it always leaned toward application to the benefit of somebody, for, in the proper sense of the term, he was a utilitarian. As soon as he was settled at Yellow Springs he began to study the deposits so well exposed in that neighborhood and quickly gained, as no others had done, a thorough understanding of their relations. His collections of fossils, made wisely and scientifically, proved of great service to paleontologists; he delivered lectures upon scientific subjects, accurate, yet devoid of technical language—lectures of a type little known at that time; he was sought as a speaker among farmers, in village lyceums, and at teachers' institutes. Within two or three years he had become the scientific authority for southwestern Ohio. When the geological survey was organized in 1869 he was appointed one of the two assistants, with the southwestern portion of the state as his district.

At that time there were few geologists. The old surveys had ended in the early forties; a few attempts had been made to organize new surveys, but only that in Illinois had attained real success. Some students had gained experience on the government expeditions in the far West, but of trained geologists there were barely a score. Professor Orton belonged to the generation beginning work immediately after the Civil War, but

he had done much more than most of those within reach, so that his assistance was sought eagerly by Professor Newberry on the Ohio survey. He began the investigation of the Silurians and Devonian, which covered most of his district; but some of the higher deposits were reached and he was compelled, under instructions from the director of the survey, to pass beyond the limits of his district and take up discussion of problems which others thought were peculiarly their own. In all respects he was the strong man of the corps. Painstaking and exact in observation; scrupulous in statement; cautious in speculation, he was called upon many times to render decisions in localities respecting which the reports were in conflict. When Dr. Newberry resigned after the publication of Volume III, Professor Orton was placed in charge. The work was in a peculiar condition. At the beginning of the survey the aids were mostly young men with little field experience, this of necessity, as trained geologists could not be obtained. Some of the work done by those observers was very defective, as the writer, one of the inexperienced aids, can testify; county reports, written independently, were not always accordant; even the general section was unsatisfactory, for identifications had been made with horizons in Pennsylvania beyond an area which had not been studied in detail. Prior to Professor Orton's appointment as director, the work along the state line had been completed for the Pennsylvania survey, and the results did not agree with those presented in the Ohio reports. All this can be said without in any wise reflecting upon those connected with the Ohio survey at the beginning, for every man labored conscientiously to the best of his ability, according to the knowledge then available. Their work, though erroneous in some of the details, resulted in great advantage to the state and in important contributions to geology.

But Professor Orton, in taking up the matter anew, saw that these errors, though apparently of slight economic importance, might lead eventually to serious results, and he set himself to correct them. How difficult the task was few can understand,

but the outcome was that masterly presentation of the whole Carboniferous series of Ohio, in which the relations and variations of every prominent bed as it occurs within the state and in adjacent portions of other states are presented in such fashion as to make the discussion distinctively one of the best yet contributed to Appalachian geology. In this the awkward task of correcting the errors of those who had made the original observations is performed with a delicacy rarely equaled. Good work is noted, but errors are referred to in such a way that to discover whose they are would require more labor than anyone would choose to expend. Indeed, the reader is inclined to believe that every error in observation was due to too earnest desire to do faithful work—which is more than half true.

During Professor Orton's term, the petroleum interests attained great importance; the origin of the oil, the mode of occurrence and the laws regulating the flow were studied with great care. At the same time and with equal care problems relating to natural gas were investigated. Professor Orton was recognized quickly as an authority upon all matters respecting petroleum and natural gas, whether scientific or technical, and he was called upon by the Kentucky, New York, and United States surveys to prepare elaborate reports; so that his writings will be the standard reference for years to come. His studies led him to issue appeals to the people of Ohio urging care in husbanding their resources; but these were not received in the spirit in which they were offered. He had the melancholy satisfaction of seeing his forebodings justified by the event. The distribution of fire and pottery clays, studied in reconnaissance by some aids on the Newberry survey, was taken up systematically and a complete investigation made under his direction by his son, who has succeeded him as director of the survey. Building stone, iron ore, glass sands, and other materials of economic interest, all received careful study. Professor Orton's reports prove the intimate relation between pure science and industrial growth.

Throughout his career, while ever anxious to improve the condition of the community by inducing men to utilize the discoveries of geology, he was ever on the alert to advance the

cause of pure science; for he always maintained that only by its rapid advance can the economic side find advance. The debt of geology to Edward Orton is very great, far greater than we are apt to think, for, in his writings, he effaced himself and often gave credit to others for what was rightfully his own. While he did much for science, he did even more for his state, many of whose industries owe the present success very largely to his efforts—efforts due solely to his anxiety for the public welfare and made without expectation of reward, pecuniary or otherwise.

But Professor Orton was more than teacher and geologist. With burdens of exacting character in the university and in the state geologist's office, he found time and opportunity for services in other directions. The city of Columbus lay near to his heart and he was indefatigable in efforts to advance its interests. He was always ready to aid in any organization looking to the public good; even the state's prisoners were objects of his care for many years. He did not neglect his duties as a citizen, but labored to secure proper candidates for political offices. His time belonged to others; he never felt himself his own.

Professor Orton was always impressed with the exceeding value of time, with the importance of utilizing moments. He was as one intrusted with an estate to be improved to the last degree before the owner's return. Every day's work was done as though that were the only day. Such conscientious devotion gave authority to his statements. Whenever his conclusions proved to be erroneous, the error was regarded as merely additional proof of the limitations of the human mind. With this spirit, whatever he did, whatever he wrote, was brought modestly as a contribution to the growing edifice of knowledge and was offered with such self-forgetfulness that recognition of its merit and of indebtedness to him appeared often to be a matter of surprise rather than of gratification. Honors came to him unexpectedly but they came often.

But while thus sensible of responsibility, Professor Orton never carried a burden. He enjoyed the companionship of his fellows; he had a keen sense of the humorous, but his humor never took the form of sarcasm; no sting was attached to any word

that cropped from his lips or pen. Many times he was compelled to assert himself forcibly, even indignantly, but no bitterness could be discovered in his rebukes. He was the incarnation of integrity; a friend who never wavered.

Little wonder that when he died, the loss to science was less regarded than was the personal loss which was felt by so many in all stations and in all callings; that the man was remembered more than a student. Those of us whose acquaintance with him began thirty years ago became attached to him in such fashion that we rejoiced when good came to him, not asking why it came but gratified that it had come to so true a man. The man has gone and now we think often of the student who deserved to the full, and more, all of the recognition which his work received. We can lay a double tribute upon his grave, one to the man whom we loved and one to the geologist who solved so many perplexing problems.

In the midst of his usefulness, in 1890, Professor Orton was stricken by paralysis which rendered his left side useless. Crippled, with his work incomplete, it seemed as though his life was to pass away in darkness. But his mental powers were unaffected and he recovered strength to such a degree that he continued to work until within a short time previous to his death. In 1899 his health gradually declined. When the American Association for the Advancement of Science met in Columbus last year, he gave an address, so much longer and so much more important than that expected from an incoming president, as to lead some to suppose that he did not expect to live until the meeting of this year. Be that as it may, the address was his last word to his fellow-workers in science. He grew perceptibly weaker after the meeting closed and, on October 16, 1899, he passed away suddenly and without pain.

Professor Orton married, in 1855, Mary M. Jennings, of Franklin, N. Y., who died in 1873. The four children of this union still survive. He married Anna Torrey, of Milbury, Mass., in 1875, who, with their two children, survives him.

JOHN J. STEVENSON.

THE GRANITIC ROCKS OF THE PIKES PEAK QUADRANGLE[1]

GENERAL RELATIONS

FEW natural features in the west are better known by name and form than Pikes Peak, which has served so often as a goal for the pioneer and traveler or as a fitting subject for the photographer and artist. Its prominence arises from its position as the landmark first seen by the traveler moving westward, and from the abruptness with which it rises 8000 feet above the plateau at Colorado Springs.

Moreover, the rapid developments in mining at Cripple Creek and the papers[2] that have recently appeared on the subject have increased the interest in the area and have directed thought to its geology.

In the present paper it is proposed to give a summary of the results obtained from a field and detailed laboratory study of the

[1] Published by permission of the Director of the U. S. Geological Survey.

The field work for the present paper was carried on by the writer while a field assistant in the party of Mr. Whitman Cross who directed the work and suggested the problems to be studied. Many of the specimens were collected by Mr. Cross, and his field notes have been used freely. For the constant willingness to give assistance and the freedom in the use of notes, the writer wishes to express his gratitude to Mr. Cross, who furnished the opportunity to study so extensive an area.

[2] WHITMAN CROSS: Intrusive Sandstone Dikes in Granite, Bull. Geol. Soc. of Am., Vol. V., 1894, pp. 225–230; Geology of the Cripple Creek Gold Mining District; Proc. Colo. Sci. Soc., June 4, 1894.

R. A. F. PENROSE, JR.: The Ore Deposits of Cripple Creek, Colo. *Ibid.*

E. B. MATHEWS: The Granites of the Pikes Peak Area, Bull. Geol. Soc of Am., Vol. VI, 1894, pp. 471–473.

WHITMAN CROSS and R. A. F. PENROSE, JR.: Geology and Mining Industries of the Cripple Creek District, Colo. Part I, General Geology, WHITMAN CROSS; Part II, Mining Geology, R. A. F. PENROSE, JR. Sixteenth Ann. Rept. Dir. U. S. Geol. Surv., II, Washington, 1895, pp. 13–217.

W. O. CROSBY: The Great Fault and accompanying Sandstone Dikes of Ute Pass, Colorado, Science, new series, Vol. V, 1897, pp. 604–607. Archean Cambrian Contact near Manitou, Colorado, Bull. Geol. Soc. of Am., Vol. X, 1899, pp. 141–164.

granular igneous rocks comprising the summit of Pikes Peak, and the area to the west of it, included within the Pikes Peak quadrangle of the Geologic Atlas of the United States. The field observations were made during the seasons of 1893 and 1894, and the laboratory studies during the succeeding winters.

The quadrangle studied contains, approximately, 930 square miles and embraces the greater portion of the southern termina-

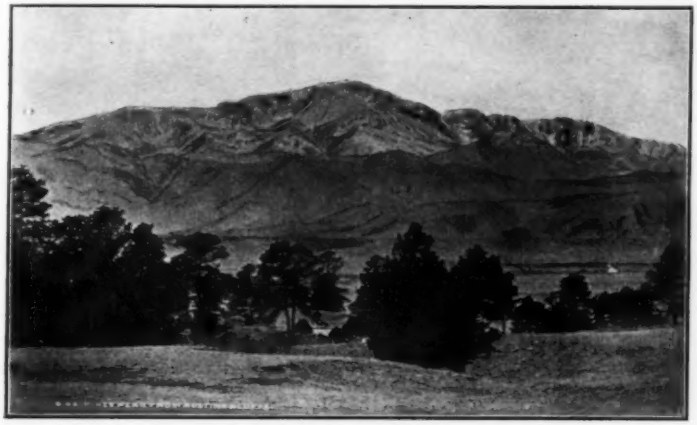

FIG. 1.—Pikes Peak seen from the plain.

tion of the Front or Colorado range in its *en eschelon* ending east of the Royal Gorge of the Arkansas. The topographic features of the area are the mountain massif on the east, rising rapidly as shown in Fig. 1, from the level of the plateau to the height of 14,108 feet above the sea. Westward from the summit the slope is much gentler, as shown in Fig. 2, to the somewhat dissected plateau of Cripple Creek and Florissant, drained on the north by the tributaries of the South Platte River and on the south by Oil Creek and its tributaries which drain into the Arkansas River The divide between these two drainages does not include the summit of Pikes Peak but passes somewhat to the north and west of the mountain mass.

The rocks of the region represent massive and schistose granites, metamorphic schists, remnants of formations belonging to the Algonkian, Cambrian, Silurian, Carboniferous, Jura-trias, Cretaceous, and Eocene periods, and numerous igneous rocks including basic breccias, massive andesite, andesite breccias, trachyte, rhyolite, phonolite, and nepheline-syenite.

The granites and gneisses of the Rocky Mountains have gen-

FIG. 2.—Pikes Peak from carriage road (13,000), (showing gentler western slope).

erally been regarded as part of the Archean complex, but it has been shown[1] that within the main granitic masses of the Pikes Peak area there are many included fragments of quartzite and of schists that show their derivation from sandstones through induration and metamorphism. These sediments are regarded as of Algonkian age, and the granites cutting these strata are accordingly either Algonkian or early Cambrian. It is deemed most in harmony with the facts in the case to refer the granitic eruptions to the late Algonkian period.

The schistosity in the gneisses was produced prior to the Upper Cambrian and this fact, together with the assumed age of the granitic eruptions renders it probable that the squeezing

[1] Pikes Peak Folio No. 7, Washington, 1895.

of the granites is due to earth movements which preceded the Cambrian.

The following pages treat almost exclusively of the granitic rocks of the area.

ROCK TYPES

The greater portion of the area studied, as shown by the accompanying sketch and the more complete map in the folio of the Geologic Atlas,[1] is occupied by granites, gneisses, and associated schistose rocks which form an undulating platform underlying the later formations. The prevailing composition of this complex is that of a typical granite with the addition of a small amount of fluorine, while the characteristic mineral constituents remain the same over an area of more than a thousand square miles, notwithstanding the fact that the exposures are representative of bodies intruded at different periods, and crystallized under somewhat different conditions. The granites are light colored, usually pinkish, holocrystalline aggregates of feldspar, quartz and biotite with occasional hornblende and fluorite. The individual components vary in their size and relative abundance and in the perfection of their crystal form ; but in almost every instance the feldspar is larger, more abundant and somewhat better formed than either the quartz or biotite. These variations in the manner of aggregation and in the size of the constituent minerals give rise to well-defined types of granite which were distinguished and plotted in the field.

Although some sixteen varieties of granite were distinguished during the mapping, later study has shown that all masses of prominence may be referred to one of four clearly defined types which have been named,[2] the Pikes Peak, the Summit, the Cripple Creek, and the Fine-grained types respectively.

PIKES PEAK TYPE

A large part of the area of the accompanying map is occupied by a single type of granite, called the Pikes Peak type, from its

[1] Geological sheet. Pikes Peak folio, No. 7, Washington, 1895.

[2] Bull. Geol. Soc. Am., VI, 1894, pp. 471–473.

prominence in the constitution of the Pikes Peak massif. This type is characterized by the relatively large size of its feldspar and quartz grains and its tendency to form conspicuous feldspar phenocrysts that often attain a diameter of several inches.

The fresh, unaltered granites of this type are coarse-grained aggregates of quartz, perthitic feldspars, and biotite with occa-

FIG. 3.—Pikes Peak type of the granite.

sional accessory hornblende or fluorite and microscopic apatite, zircon, titanite, magnetite, rutile, hematite, limonite, epidote, and allanite.

The grain varies widely from extremely coarse where the feldspar phenocrysts are six inches long to the more normal granite in which the length of the feldspar grains is little more than a quarter of an inch. The usual diameter for the feldspar is about half an inch, and for the quartz, a quarter of an inch to an eighth of an inch. The biotite areas, although generally smaller than the quartz grains, are sometimes a half inch in width. (Fig. 3.)

The texture of this type presents all grades of transition from that in which the feldspar is only slightly larger than the quartz to one in which the feldspar stands out in large, imperfectly formed porphyritic crystals.[1]

The areal distribution of the rocks showing such increase in the development of the feldspar is not clearly defined, although there is a faint suggestion of a concentric wrapping about the lower slopes of Pikes Peak.

A mechanical separation shows the constituent minerals of the Pikes Peak type to be in the following proportions by weight:

Quartz	33.4
Microcline	53.3
"Biotite"	10.7
Oligoclase	2.6
	100.00

The "biotite" includes all of the minerals with a greater specific gravity than 3.0.

The quartz occurs in large irregular or oval, colorless or smoky grains distinctly outlined against the feldspar and biotite towards which it is usually xenomorphic. In one instance, a basal section of quartz presented three systems of cracks intersecting at 60° representing an imperfect rhombohedral cleavage probably due to mechanical deformation. The extinction ranges from completely simultaneous to mottled or undulatory.

The inclusions observed are arranged according to one of three ways. (1) The small and irregularly shaped inclusions occur either in long thin lines parallel to the rhombohedron, in broader unoriented zones, or irregularly massed in definite parts of the quartz individuals. (2) The small, somewhat rectangular cavities are arranged in indistinct lines parallel to their longer directions but not related to the crystallographic directions of the quartz. (3) The fine, hair-like "needles" have a linear arrangement and seem to occur when the other inclusions are

[1] The coarse-grained granite in which the feldspar phenocrysts are large and generally well formed, is sometimes called the "Raspberry Mountain granite," from its conspicuous development on that mountain.

fewer and more evenly disseminated through the quartz. The mineral nature of the last group could not be determined. The individual inclusions are minute apatites and zircons, hematite plates and magnetite.

Quartz occurs in some of the slides as an inclusion in the feldspars. It is probably secondary in both the microcline and the oligoclase, though in the former it may possibly be original. With the feldspar quartz forms micropegmatitic intergrowths in the more weathered and crushed specimens, but this is lacking in the fresh, unaltered rocks.

The feldspars in the Pikes Peak type vary in size, shape, composition, and age. The color is generally pink or gray, or both where there is a zonal structure. The most important feldspar is microcline perthitically intergrown with albite. This always shows the characteristic "microcline twinning" in all sections inclined to the brachypinacoid. The mesh of the rectangular grating is very small in all those instances which are regarded as original. In the small secondary flakes, however, the mesh is much coarser.

The inclusions within the microcline are albite, quartz, oligoclase, biotite, and the earlier products of crystallization. The most abundant are perthitic pegs of albite, and their disk-like cross-sections. The former lie approximately parallel to a steep positive macrodome in a plane normal to the edge (001) (010). The small round disks may easily be confused with the pellucid quartz from which they can be separated only by the use of converged polarized light.

Oligoclase is only of subordinate importance in the Pikes Peak type where it occurs in small light gray-green anhedral areas with characteristic polysynthetic twinning, lamellae showing on the base an extinction angle of 2°–3°. The inclusions lie close together near the center of the plagioclase plate and are surrounded by a zone of clear feldspar from which they are more or less sharply defined. The cause of the presence and position of these inclusions is not known. The usual explanation based on the increased basicity and consequent instability of the core

may apply, but the same phenomena may be the result of variations in the conditions during solidification. With the less viscous state of the magma during the early stages of solidification the supply of material is abundant and the growth rapid. The imperfections in crystallization increase with the rate of consolidation, through the inclusion of interpositions and the imperfect filling of space. As the magma on cooling becomes more viscous, thereby decreasing the easy transfer of material and the consequent rate of growth, the molecular arrangement of acquired material on the growing crystal is more perfect in its outer zone. This difference in homogeneity between the core and exterior is sufficient to develop a tendency towards molecular rearrangement in the interior whenever the physical conditions are changed. The sharpness of the limits is determined by the growth lines as in twinning lamellae or zonal structures.

Biotite occurs either as individual flakes or small aggregates presenting the appearance of single flakes to the unaided eye. The mica is strongly pleochroic in brown and yellow, and has an optic angle of 10°. Since the plane of the optic axes was found in several instances to lie perpendicular to the leading ray of the percussion figure, much of the mica is probably anomite.

Hornblende is relatively rare in all the granites of the area. It occurs most often in the Pikes Peak type associated with biotite and titanite. The amount of mica decreases somewhat when hornblende is present, while an increase in the latter is generally accompanied by an increase in the titanite. The hornblende-bearing granites occur in somewhat circumscribed areas below Green Mountain Falls, along the railroad east of Florissant and in the hills east of Lake George.

The accessory minerals enumerated on a preceding page occur in varying amounts. They are usually in small crystals, and belong to the earlier stages of consolidation. Titanite and fluorite are of especial interest, since the former has been found only in this type while the latter is rare, though abundant in the Summit type. Neither presents any mineralogical peculiarities.

Among the alteration minerals resulting from the weathering or metamorphism of this type are epidote and sericite associated with the feldspar; and calcite, chlorite, and muscovite accompanying the biotite.

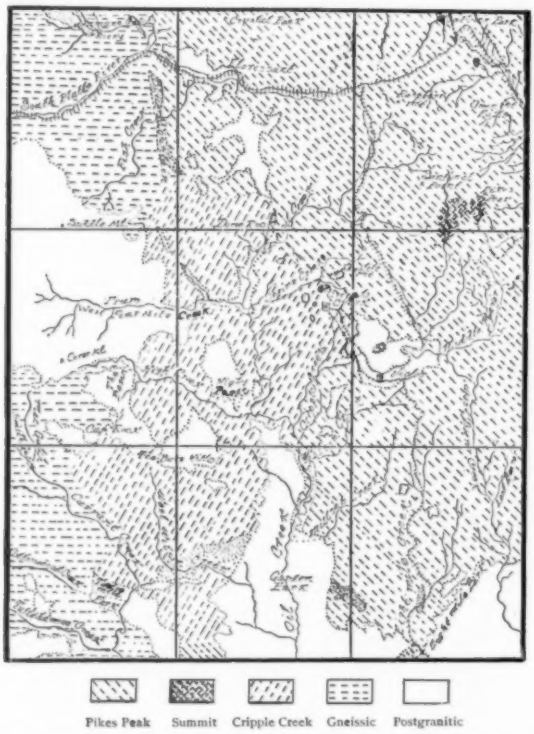

FIG. 4.—Sketch map showing the distribution of the various types of granite occurring in the Pikes Peak quadrangle.

Distribution.—The granites of this type extend northeastward from a sinuous line drawn through the lower slopes of Blue Mountain, Dome Rock, Cripple Creek, and Oil Creek Canyon to the southeastern border of the Pikes Peak Quadrangle. (Fig. 4) The limits beyond the area of the Quadrangle have not been

examined, but are shown in a general way in the maps of the early Hayden survey some miles to the north and east of the Pikes Peak area. Similar rocks have been described from the Platte Canyon in Jefferson county for the Educational Series of the United States Geological Survey.[1]

In its distribution the Pikes Peak type, in the contact with each of the three remaining types distinguished, appears as the older type. It is therefore the oldest granite in the area. The best place for studying the age of this type is in the region about the summit of the massif. Here it is cut by many dikes of the Summit type, which seem to radiate from the central eminence. The actual contact between the two granites is rarely evident in this area, however, as the blocks of the Summit type have formed a slide slope which masks the more easily disintegrating coarse-grained granite. Wherever the contact is observable, as in Wilson Creek southeast of Cripple Creek, the finer rock is seen to cut the coarser. The relations with the Cripple Creek type are poorly defined, as the exposures almost always show small masses of metamorphosed sediments at the immediate contact. The greater age of the Pikes Peak type is shown, however, in several exposures, as, for example, on the north side of Caylor Gulch at an elevation of 8600 feet, where a fine-grained saccharoidal granite of the Cripple Creek type cuts the coarser schistose granite which is correlated with that of the Pikes Peak type.

Weathering.—The processes and results of weathering in the Pikes Peak type are among its most characteristic features. The light pink color becomes darker on exposure and passes into a deep red through a bleaching of the biotite and the subsequent staining of the feldspars and quartz with the liberated iron oxide. The physical changes due to weathering are, however, more manifest. The rock disintegrates before it is decomposed. For this reason the hills are rounded and covered with granite gravel when the disintegrated material remains, and rugged or steep where the débris has been carried away. Fig. 2 gives a view of

[1] Bull. U. S. Geol. Surv., No. 150, Washington, 1898, pp. 172–177.

Pikes Peak from the northwest at an elevation of 13,000 feet, which well illustrates this difference. On the west the mountain slopes with smooth rounded outline into the drainage of Beaver Creek, while on the east the descent is precipitous in ragged cliffs, sometimes resembling huge cyclopean masonry. Counteracting this physical disintegration are chemical changes which

FIG. 5.—Disintegrated bowlder of granite showing surface hardening and disintegration beneath.

protect the rock at first, but ultimately, in conjunction with the physical forces, accelerate the rate of rock-weathering.

The effect of weathering extends for a distance of two or three feet beneath the surface of the exposed rocks. On the exterior there is frequently a dense crust, or glazing, rarely more than half an inch thick, covering a second zone several inches wide, in which the mineral are stained with iron and loosely held together. Beneath this zone the rock is often so incoherent that it seems ready to fall to pieces. The crumbling mass, in turn, passes gradually into the solid rock. Fig. 5 represents a bowlder with the coating on the surface and the disintegrating rock beneath. In this view the upper surface appears

more resistant to the weathering agencies, while the friable rock beneath has fallen away leaving the crust as a projecting edge. Such a crusting over friable material often leads to fantastic shapes, as represented in Fig. 6. The final result of the weathering is the formation of a thick coating of talus and granite gravel, composed of relatively fresh fragments of the rock and its mineral constituents.

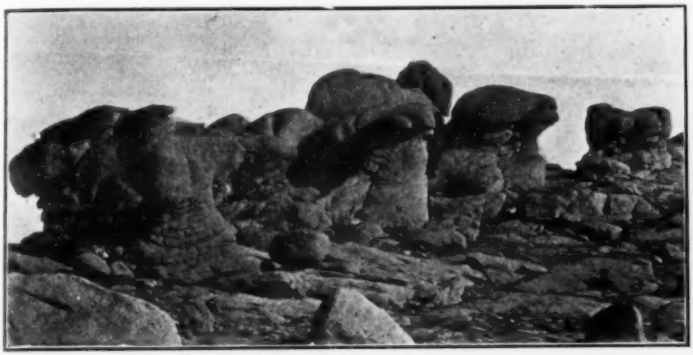

FIG. 6.—Fantastic forms due to weathering and surface hardening.

SUMMIT TYPE

The rocks of the Summit type show a very constant texture closely allied to that of granite-porphyry (Fig. 7). They are composed essentially of small gray feldspar phenocrysts embedded in a finely granular aggregate of hypidiomorphic, quartz, smaller feldspars, biotites, and minute grains of fluorite. Microscopic zircon, magnetite, hematite, and micropegmatitic intergrowths of quartz and feldspar are also present.

When fresh the color of the rock is purple, ranging from purple-violet to carmine-purple.[1] As the rock becomes weathered the color becomes less pronounced and fades to light neutral gray and brown.

The minerals composing the Summit type differ very slightly from those described under the preceding type. Quartz is more

[1] Nos. 23_p and 26_r of Radde's International Farben scala.

abundant and in smaller areas, and the numerous fine grains in the groundmass are free from much included matter. The larger individuals, however, present the broad zones of inclusions noticed in the preceding type. The porphyritic feldspar is microcline, as in the first type, but here the perthitic intergrowths of albite are much less common. The microcline also

FIG. 7.—Summit type fine grained granite-porphyry.

composes much of the groundmass where it fills the interstices between the grains of quartz. Untwinned clear grains of feldspar, probably orthoclase, are also present in the groundmass in considerable abundance. Oligoclase showing fine twinning lamellae is more poorly developed than in the Pikes Peak type. All of the feldspars are much clouded with alteration products, especially by sericite and some iron compound, either hematite or limonite. The abundant development of micropegmatitic intergrowths of quartz and microcline in this type is noteworthy, as these are practically wanting in the fresh Pikes Peak granite. The

quartz occurs in small oval, or irregular, disks which have the same orientation over considerable areas of the feldspar. Although these disks may lengthen out, they do not have the branching-radial arrangement characteristic of some of the other occurrences.

The biotite occurs in flakes without good crystal outline, and locally shows quite an advanced stage in the alteration towards chlorite and lenses of quartz formed between the foliae. The same slide may show perfectly fresh pieces of biotite associated with that which has become thoroughly chloritized. Unlike the mica of the Pikes Peak granite, the biotite of the Summit type is of the first order with the plane of the optic axes parallel to the principal ray of the percussion figure.

Hornblende, titanite, and magnetite are practically wanting in this type, although a few fresh irregular grains of the latter were noticed in a single slide.

The most characteristic mineral in the Summit type is fluorite. This is present in every section but one made from the Summit granites. It is commonly in small irregular areas and rarely in well-defined crystals. When the crystal contours are evident the little squares suggest either cubes or octahedrons. The mineral is especially characterized by a highly perfect octahedral cleavage which is well developed in the larger areas, but is lacking in the minute crystals. The anhedral areas are clear and either colorless, purple, faintly pink, or green. The pigment is unevenly disseminated through the grains, and seems to be more intense about inclusions than in the clearer parts of the mineral. Between crossed nicols the areas remain perfectly isotropic, and in ordinary light the mineral shows a shagreened surface corresponding to its very low index of refraction. All of the properties enumerated are characteristic of fluorite. The view that this is fluorite is corroborated by the high percentage of fluorine in the bulk analyses and the presence of fluorides in the veins of adjacent areas.[1] Microchemical tests were made, but failed to give conclusive results.

[1] E. g., St. Peter's Dome (Bull. U. S. Geol. Surv., No. 20), and Cripple Creek (Sixteenth Ann. Rept. U. S. Geol. Surv., II, 1895).

Although the gold ores and the fluorite are sometimes intimately associated in the mining area near Cripple Creek, no indications of gold, sulphides, or tellurides were seen in any of the sections of the Summit type.

Distribution.—The rocks of the Summit type are confined to a small area about the Summit and down the western slope of the highest part of Pikes Peak, and the relation between them and the other granites is only seen in a few places. On the main peak there seems to be a system of radiating dikes, but the contacts are not well exposed in place. In Wilson Creek canyon and near the intersection of Spring Creek with the Cripple Creek-Florissant road there are dikes of granites correlated with that of the Summit type which clearly cut the older Pikes Peak granite.

Towards the other granites this type seems to be older, since it is never found in them, while they occur in small masses within its areas.

Weathering.—In the manner of their weathering the rocks of the Summit type show many differences from those of the Pikes Peak type. Instead of disintegrating into massive, rounded bowlders and coarse gravels like the latter, the granite-porphyry breaks up into smaller angular blocks, as illustrated in the familiar views of the Upper Station of the Pikes Peak Railway. These blocks and many of the ledge exposures, moreover, have a glazed crust similar to that observed on bowlders of the Pikes Peak type. What the nature of the process is which produces this surface was not determined in the somewhat hasty survey of the upper portions of the mountain, although the natural surroundings suggest three possible agencies for such polishing, viz., blown sand, ice, and chemical action. The smoothness of the surfaces and the occurrence of polished surfaces in sheltered hollows is against any polishing by sand, while the presence of a crust on somewhat recently formed bowlders and steep slopes, and the absence of glacial striae militate against any explanation based on ice action. The thickness of the shell and the decayed character of the interior, on the other hand, seem to indicate that

this crust is due to chemical action. The great diurnal changes in temperature, the dryness of the air, and the direct action of the sun tend to promote rapid changes in the amount of moisture present, and this in turn would cause alternations of solution and precipitation. Throughout the nights and the winter seasons the rocks receive by capillary action a considerable supply of moisture which during the day and the summer would take some of the material from the interior and carry it to the surface, where there would be rapid evaporation and precipitation. Such action must be slow, as the material carried out is but slightly soluble even under favorable conditions; and yet this very insolubility helps in the final result by rendering at least a portion of the deposited material independent of the rains. The increased amount of silica in the crust seems to corroborate this hypothesis of chemical action.[1] The formation of a crust on the rhomboidal joint blocks, together with the closeness of grain of the rock accounts in great measure for the angularity of the blocks strewn over the summit, and may in part account for the present topographic preëminence of this portion of the massif.

CRIPPLE CREEK TYPE

The granites grouped under this title, compared with those of the preceding types, appear finer than those of the Pikes Peak type and more evenly grained than those of the Summit type. They are finely coherent saccharoidal aggregates of microcline, vitreous quartz, and glistening biotite with occasional microscopic individuals of zircon, hematite, magnetite, and apatite. When phenocrysts are present they are usually microcline, although in an exposure at the Placer Mill northwest of Cripple Creek, broad glistening flakes of biotite are porphyritically developed.

The most prominent constituents are small, rectangular crystals of fresh pink microcline which occasionally reach the length of half an inch (Fig. 8). The twinning network is medium coarse

[1] CROSBY (Merrill, Rock Weathering, p. 255) suggests also the deposition of iron oxide.

and therefore differs from that of the other types. This mesh, however, is not as coarse as that in the smaller, probably secondary, microclines present in the same slides, and in the altered granites more fully described elsewhere. Perthitic intergrowths with albite are not prominent in the majority of the sections, but are very abundant in the slides representing some of the

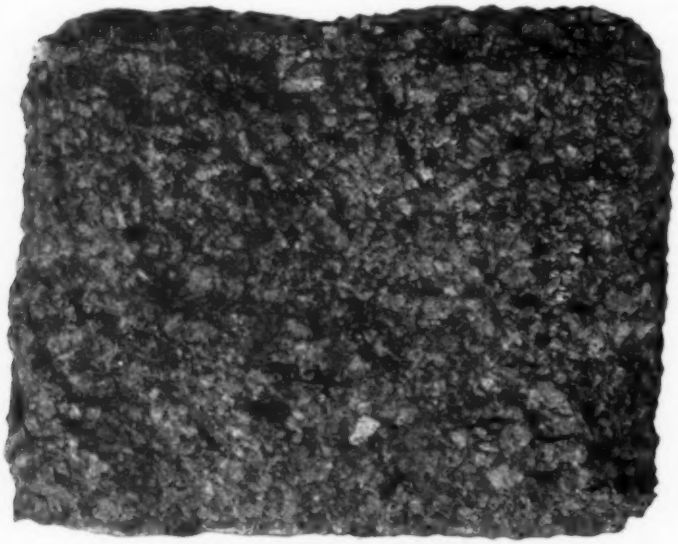

FIG. 8.—Cripple Creek type of the granite.

granites from the vicinity of Seven Lakes. The microclines of this locality are twinned parallel to the basal pinacoid, according to the Manebach law, and differ only in size and occurrence from the large and beautiful amazonstone and orthoclase so well known from this area. The perthitic lamellae meeting at the composition face (001) form an angle of 147° and in each case lie a few degrees from the vertical axis in obtuse β (parallel to a steep positive orthodome).[1]

[1] In color and texture this rock resembles the well-known granite from Red Beach, Me., described in the Tenth Census, and it is probable that if similar rock can be found where the conditions of quarrying and transportation are favorable it will prove of economic interest.

The irregularly oval grains of quartz composing from one seventh to one quarter of the rock-mass are either clear and vitreous, as in the granites from Seven Lakes, or small and stained with iron, as in the rocks collected in Caylor Gulch. They are somewhat poor in fluid inclusions but show a great number of fine "quartz-needles." The iron-staining occurs as a filling in the cracks, rather than as a minutely disseminated pigment or fine evenly distributed hematite flakes.

Like the granites of the Pikes Peak type, those of the Cripple Creek type do not have very much micropegmatite developed in the fresh specimens, and when it is developed the quartz does not show the arborescent and radiate growths so abundant in the weathered and metamorphosed rocks, but is present in small rounded disks or ovals similar to those described by Romberg.[1]

The plagioclase occurs in small anhedral grains which are older than the quartz and the microcline. They are generally clouded with alteration products which may be either irregularly distributed through the individual; arranged parallel to the twinning lamellae; or concentrated in the center with a surrounding clear zone in similar optical orientation. The twinning lamellae, according to the albite law, are very fine and usually extinguish almost simultaneously parallel to their composition face.

The other constituents, zircon, apatite, and magnetite, show no unusual features and are very sparingly developed.

Distribution.—The granites of the Cripple Creek type are most characteristically developed in the area lying to the west of a line drawn from Lake George to the town of Cripple Creek and thence in a somewhat sinuous line to the waters of Oil Creek. Between this line and the volcanic deposits on the west is a broad stretch of relatively level country considerably dissected on its eastern side by Oil Creek and its tributaries.

The contacts against the Pikes Peak type are generally obscured by the presence of narrow bands of highly metamorphosed schists which were included in the older type and cut by

[1] N. J. B. B–B. VIII, 1892.

the granites of the Cripple Creek type in a manner well shown near the mouth of Arequa Gulch a few miles below the town of Cripple Creek. On the west the contacts with the gneissic granite are generally obscure, though the finer grained may be seen cutting the coarser and more schistose rock in Caylor Gulch at an elevation of 8600 feet.

The manner of weathering and the resulting physiographic forms are intermediate between those of the Pikes Peak and Summit types. The hills are neither so smooth, so bold, nor so massively jointed as those composed of Pikes Peak granite; while the disintegrated fragments are not as compact and angular as those of the Summit type. The mineralogical changes are those common to granitic minerals.

FINE GRAINED TYPE

The rocks included under this head do not occur in well-defined masses extending over large areas but in small dikes distributed throughout the entire area studied. Nor are they so closely allied in their mineralogical and textural features as members of the preceding three groups. Their correlation is based upon their composition and texture, mode of occurrence, age, and present topographic position rather than upon their areal continuity. All of these rocks are fine grained hypidiomorphic granular aggregates of reddish color, composed of quartz, feldspar, and one or both kinds of mica, with small amounts of microscopic fluorite, magnetite, epidote, zircon, and apatite.

The color of these rocks varies from brilliant red to pinkish-white or dull yellow, but is usually bright pink. In the latter case the feldspars are stained by finely disseminated iron oxide. The size of the individual grains is very constant, and rarely exceeds one sixteenth of an inch. Among the individual constituents there are several points of difference from the same minerals in the earlier types. Quartz is more abundant and in grains as large or larger than those of microcline, while incipient granulation shown by a mottled extinction is more frequent.

Among the feldspars, microcline shows a slight increase in the size of its twinning network and the plagioclase a decrease in the size and abundance of its grains. Perthitic intergrowths are practically wanting in these rocks, whether fresh or altered, while micropegmatitic intergrowths are abundant, especially in the slides where the evidences of mechanical deformation are

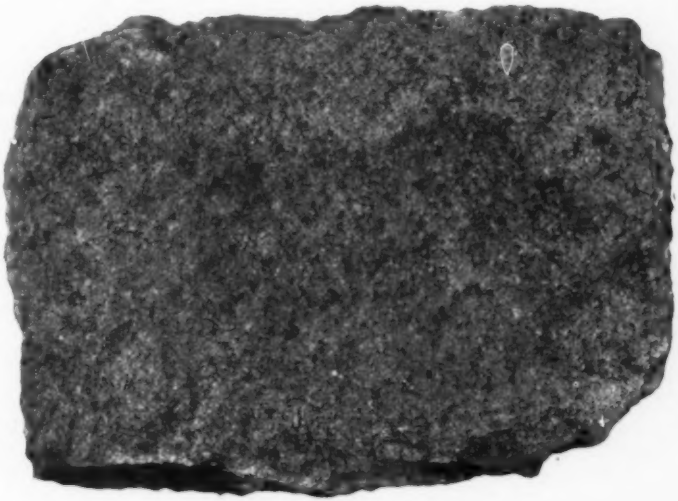

FIG. 9.—Fine grained type of granite.

most numerous. The micas show no unusual features beyond the occasional inclusion of tiny individuals of fluorite showing well-defined crystal outlines in fresh flakes of biotite.

Weathering.—The effect of atmospheric action on the fine-grained granites varies somewhat, but is ordinarily less pronounced than that on the other three types. When the rock disintegrates it usually falls into a mass of angular bowlders of small size, which are quite compact and sometimes covered with a surface glaze. This coating, which is faintly shown in Fig. 9, is much less clearly defined than is that on the Pikes Peak or

Summit types, and it does not appear to be as commonly developed. Ledge exposures of this type are comparatively rare, as the solid rock is usually covered by angular bowlders. The relatively greater resistance to weathering, due probably to the more compact texture of the rock, is clearly brought out in the topographic position of its exposures. When the fine-grained granite occurs in any considerable mass it forms the tops of minor hills and ridges. This is well shown in many places within the area of the map, the best illustration occurring on the subordinate ridges of the slopes of Pikes Peak and in the rugged area between Grouse Hill and Red Mountain, on the sides of the canyon of Cripple Creek.

TABLES SHOWING THE COMPARATIVE ABUNDANCE AND SIZE OF THE CONSTITUENTS OF THE DIFFERENT TYPES

The comparative abundance, size, and development of the various constituents in the four types of granite described in the preceding pages, are summarized in the following tables:

TABLE I. SHOWING RELATIVE ABUNDANCE OF MINERALS

	Pikes Peak	Summit	Cripple Creek	Fine grained
Quartz	abundant	abundant	abundant	predominant
Microcline	predominant	predominant	predominant	predominant
Orthoclase		fairly commonly		
Oligoclase	constant	constant	constant	constant
Perthitic intergrowths	well developed	unusual	not marked	
Micropegmatite	very rare	very abundant	rare	present
Hornblende	present			
Biotite	abundant	abundant	present	present
Muscovite				common
Fluorite	rare	very marked		present
Apatite	constant	rare	rare	present
Zircon	constant	present	constant	constant
Titanite	present			
Epidote	rare			present
Magnetite	present	rare	present	present
Hematite	present		present	present

TABLE II. SHOWING RELATIVE SIZE AND DEVELOPMENT

	Pikes Peak	Summit	Cripple Creek	Fine grained
Quartz				
Size	3–10^{mm} 5^{mm} average	2–4^{mm}	3–5^{mm}	1–3^{mm}
Form	irregular	spheroidal	irregular	irregular
Microline	(Phenocrysts)			
Size	6"×3" to 15×30^{mm}, 20×30^{mm} as	25×15 to 4×7^{mm}	7×5^{mm}	
Form	well developed	well developed	well developed	
Microline	(Groundmass)			
Size	10×15^{mm}	2.×.05^{mm}	1×3^{mm}	1×2^{mm}
Form	irregular	irregular	irregular	irregular
Biotite				
Size	3–4^{mm}	1–2^{mm}	1^{mm}	0.5–1^{mm}
Mode of aggregation.....	single and aggregate	single and aggregate	single and aggregate	single or aggregate
Texture				
Coarseness ...	coarse	Medium to fine	medium	fine
Arrangement ...	granular to porph. gran.	granitophyric	saccheroidal to orthophyric(?)	granular
Mode of occurrence	large masses	small masses and dikes	large masses	small masses and dikes

The accompanying tables show at a glance the marked similarity in the mineralogical composition, and the equally marked diversity in the textural relations presented by the different types. The diversity in the mineralogical composition of the different types is no more than that due to the presence of occasional orthoclase, hornblende, sphene, muscovite, or epidote in specimens collected over an area of more than nine hundred square miles. These types, it is true, show well developed perthitic intergrowths to be common in the fresh granites of the Pikes Peak type and wanting in the other types; while fluorite and micropegmatite are prominent in the rocks of the Summit type and unusual in the rest of the unaltered granites. The most striking, most constant, and most characteristic differences between the types are, however, in the relative and absolute size

of the constituents, and not in the specific character of the minerals present.

The second table shows a variation in the size of the quartz constituent from grains averaging 5^{mm} in diameter in the Pikes Peak type to those of $\frac{1}{3}^{mm}$ in the fine grained granite. A similar variation is noticeable in the mica, from flakes of $0.5–1^{mm}$ in the fine grained type to those of $3–4^{mm}$ in the Pikes Peak type. The microclines also show a similar change in the same direction, whether they are phenocrysts or not; and in addition the fine-grained granites show no feldspars porphyritically developed. This uniform change in the size of the constituents can only result in the production of a similar variation in the coarseness of grain, as shown in the tables.

Table I, together with the chemical composition of the rocks, brings out the similarity or family likeness existing between the different granites; a likeness that signifies their origin from a common magma relatively rich in silica and fluorine. Table II, with the field relations, substantiates this view and explains the many local differences shown in texture, or mode of aggregation, of the different constituents. The coarse-grained Pikes Peak and Cripple Creek granites formed large masses, while the Summit and fine grained rocks occur in physical conditions sufficiently variable to account for the variations in texture which distinguish the rocks of these types.

CHEMICAL COMPOSITION

The marked uniformity in the mineralogical composition of the various granites from all portions of the area suggests a similar uniformity in the chemical composition. The abundance of quartz and perthitic microcline, with the small amounts of plagioclase, mica, and accessory minerals, indicate a relatively high percentage of silica and the alkalis, with a comparatively small amount of calcium, iron, and magnesium. The presence of fluorite, also, suggests the actually small, but relatively high, percentage of the unusual constituent fluorine. These inferences from the mineralogical composition are fully sustained by the

following complete and careful analyses made by Mr. W. F. Hillebrand of the U. S. Geological Survey.

TABLE OF CHEMICAL ANALYSES

	I (2128)	II (2531)	III (2530)	IV (2369)	V
SiO_2	77.03 1.284	75.17 1.253	73.51 1.225	73.90 1.221	74.90 1.248
TiO_2	.13 .001	.10 .001	.18 .002	.07 .000	.12 .001
Al_2O_3	12.00 .116	12.66 .122	13.28 .129	13.65 .132	12.89 .125
Fe_2O_3	.76 .004	.23 .001	.94 .006	.28 .001	.58 .003
FeO	.86 .012	1.40 .019	.97 .013	.42 .005	.91 .012
MnO	tr.	tr.	tr.	tr.	.....
CaO	.80 .014	.83 .014	1.11 .020	.23 .004	.74 .013
SnO	.....	tr. ?	.....	.....	.....
BaO	tr.	.03	tr.	tr.	.....
MgO	.04 .001	.05 .01	.05 .001	.14 .003	.07 .001
K_2O	4.92 .052	5.75 .061	5.22 .055	7.99 .085	5.92 .063
Na_2O	3.21 .051	2.88 .046	3.79 .061	2.53 .040	3.10 .050
Li_2O	tr.	st. tr.	tr.	tr.	.....
H_2O*	.14	.16	.16	.15	.15
H_2O†	.30	.62	.31	.92	.55
P_2O_5	tr.	.03	tr.	.05	.02
Fl	.36	.31	.55	.....	.31
CO_2	.....	.....	.....	.....	.....
	100.55	100.26	100.38	99.75	.....
O less F	.15	.13	.22	.....	.....
	100.40	100.13	100.16	99.75	100.26

*Below 110° C. †Above 110° C.

I. (2128.) A coarse grained granite of the Pikes Peak type taken from the western side of the Pikes Peak massif at a place

called Sentinel Point (12,300 feet). Feldspar is the most important constituent, with quartz very abundant in somewhat smaller grains. The mica occurs in both single individuals and in aggregates of minute flakes. A thin section of this rock is composed, almost entirely, of quartz and microcline, the latter showing a few lamellae of perthitic plagioclase.

II. (2531.) A porphyritic granite of the Summit type collected from the divide tunnelled by the Colorado Springs Water-works (elevation about 12,000 feet). This is composed of feldspars and large grains of quartz in a fine grained, reddish to purplish groundmass.

III. (2430.) A fine grained variant of the Summit type collected on the head waters of the Middle Beaver, nearly opposite the Bear Creek road to the Colorado Springs Water-works. The prominence of the biotite against a fine grained groundmass of feldspar, and the peculiar purplish hue due to the disseminated fluorite, are the chief characteristics.

IV. (2369.) A fine grained granite of the fourth type taken from Smith's Gulch not far from Current Creek P. O. This is composed of quartz and microcline with small amounts of mica.

V. An average of the preceding.

The following conclusions based on a comparative study of the analyses seem to be warranted by the figures. When the individual analyses and their average are reduced to molecular proportions and compared with an average of twelve type analyses given by Zirkel[1] and several analyses given by Rosenbuch[2] similarly reckoned, it is seen that they all are richer in silica than the averages given in the text-books, though not richer than individual specimens from many areas. The sum of the alkalis seems to conform to that of the averages but the granites of the Pikes Peak area are relatively richer in potassium. This relation between the alkalis becomes of additional interest when the occurrence of nepheline-bearing rocks near Cripple Creek is considered.

[1] Lehrbuch der Petrographie, 2te. Aufl. II, p. 29.

[2] Elemente der Gesteinslehre, p. 186.

Among the elements represented, fluorine is of the most interest. Although small in amount the still smaller quantities of lime and phosphorus show that there is enough present to satisfy all of the latter even in the form of pure fluor-apatite, and much of the former in the form of fluorite. The possible excess of calcium is so small that the plagioclase plates must be sodium rich oligoclase and the perthitic pegs albite.

The low percentage of iron and magnesium together with the strong pleochroism of the mica explains the relative scarcity of this mineral.

The chemical analyses confirm the microscopic determinations and show that the general magma was of such a composition as might produce a rock composed essentially of a potassium feldspar, perhaps intergrown with albite, and considerable quartz, with small amounts of fluorite and iron rich mica.

RÉSUMÉ

The area included within the Pikes Peak quadrangle is a complex of granites, gneisses and schists overlain by numerous sedimentary and volcanic rocks of later age. The unaltered granites show, over an area of more than a thousand square miles, a notable uniformity in their mineralogical and chemical composition which is marked by the persistent presence of holocrystalline quartz-microcline aggregates bearing small amounts of equally constant biotite. On the other hand, these same rocks show a distinct diversity in the abundance, size, and form of their constituent minerals and the consequent differences in texture.

The variations in texture and composition are as follows:

Pikes Peak type.—Coarse granular to coarse porphyritic: rich in perthitic feldspar, poor in micropegmatitic intergrowths, and fluorite with occasional hornblende and titantite.

Summit type.—Granitophyric; poor in perthitic feldspars but rich in micropegmatite and fluorite.

Cripple Creek type.—Saccharoidal with rectangular feldspars; poor in perthitic feldspars, micropegmatite, and fluorite.

Fine grained type.— Fine granular; poor in perthitic feldspar, micropegmatite, and fluorite but bearing some muscovite.

Emphasis has often been laid on the variations in the chemical or mineralogical composition of masses showing uniformity in their texture. The present instance represents on a large scale the opposite changes. Here there are well-defined differences in texture in a mass of uniform chemical composition. The changes in mineralogical composition are slight, and represent little or no difference in the chemical proportions of the mass except in the case of the fluorite. The other changes are local and partake of the nature of "dark patches."

Besides these original differences in the textures there are others of secondary origin where the feldspar phenocrysts have become lenticular "eyes" and the massive granites have been changed to granite-gneisses.

EDWARD B. MATHEWS.

A NORTH AMERICAN EPICONTINENTAL SEA OF JURASSIC AGE

I. Introduction.
  1. Statement of the lines of investigation.
II. Nature and extent of the sea.
  1. Present known distribution of the deposits.
    a') South Central Wyoming area.
    b') Southeastern Idaho area.
    c') Northern Uinta area.
    d') Southern Uinta area.
    e') Southern Utah area.
    f') Black Hills area.
    g') Montana area.
    h') Canadian area.
    i') Aleutian area.
  2. Conclusions.
III. Relation of the interior fauna to the northern Eurasian fauna.
IV. Connection of the sea with the ocean.
V. Lack of communication between the Californian province and the interior, and the causes assigned.
  1. The climatic hypothesis.
  2. An alternative hypothesis.
VI. General conclusions.

INTRODUCTION

The following line of investigation is the out-growth of the study of the faunal and stratigraphical conditions as they are expressed in the Jurassic formation of the Freeze-Out Hills in southern Wyoming.[1] In making these investigations the writer has been led to test, in the light of new doctrines[2] and more recent observations, certain prevalent opinions bearing on Jurassic faunal geography. In connection with these investigations there arose also questions concerning which no definite statement

[1] LOGAN: Kansas Uni. Quart., April 1900.

[2] See papers by DR. T. C. CHAMBERLIN on: "A Source of Evolution of Provincial Faunas," JOUR. GEOL., Vol. VI, p. 598; "The Ulterior Basis of Time Divisions," *ibid.*, p. 449.

of opinion has as yet appeared in our geological literature. Among the lines of investigation which suggested themselves were the following: (1) The nature and extent of the interior Jurassic sea; (2) the relation of the interior fauna to other faunas; (3) the connection or connections of the sea with the ocean; and (4) the causes for the lack of communication between the Interior province and the Californian faunal province.

Some of these questions, notably the second and fourth, have already received a somewhat exhaustive discussion at the hands of a number of geologists. In the majority of cases, however, the conclusions formed have been connected with certain fundamental assumptions concerning the validity of which there is at present profound skepticism. As these new doctrines are more or less intimately associated with new fundamental hypotheses, a test of the one is in a measure a test of the other; but a discussion of original postulates does not fall primarily within the province of this investigation. Therefore the discussion will proceed along the lines already indicated and in the order above mentioned.

Nature and extent of the sea.— In order to present the data upon which our conclusions concerning the nature and extent of the Jurassic sea are based it will be necessary to give a summary of the stratigraphical and faunal conditions of the present known Jurassic areas. In collecting this data I have consulted the writings of a long list of geologists who have labored in this particular geological field.[1] On the whole it may be said that the results obtained by these men are strikingly harmonious; so that no grave difficulty should be met in any attempted logical interpretation of the facts.

These Jurassic areas will be discussed in the order which follows: (1) The South Central Wyoming area; (2) the Southeastern Idaho area; (3) the Northern Uinta area; (4) the Southern Uinta area; (5) the Southern Utah area; (6) the Black Hills area; (7) the Montana area; (8) the Canadian area; (9) the Aleutian

[1] For references see following discussion.

area. Many of these terms have been used in a loose geographic sense since the object is to include under one name all of the minor localities belonging to one areal province. The numbers on the map[1] indicate the position of these areas.

THE SOUTH CENTRAL WYOMING AREA

The Freeze-Out Hills.[2]—The oldest rocks recognized in the Freeze-Out Hills are the Carboniferous. They occupy the center of the partly dissected anticline and are overlain by the Red Beds which are composed of sandstones and reddish arenaceous clays and marls inclosing here and there lenticular masses of gypsum or gypsiferous clays. These beds are seemingly devoid of fossils and are apparently conformable with the overlying Jurassic beds of unquestionable marine deposition. At a point on the Dyer Ranch the following stratigraphical conditions of the contact between the Red Beds and the Jura were noted in ascending order:[3]

1. Base, near top of the Red Beds, reddish clay, 2′+;
2. White, indurated sandstone, 4″;
3. Clay, light red, 5″;
4. White sandstone with a reddish tinge, 1″;
5. Light red clay, 2″;
6. White, slightly indurated sandstone, 6″;
7. Shale, reddish changing to purple, 4′;
8. White fissile arenaceous limestone, 6′;
9. Arenaceous clay of a dull red color, 10′;
10. White laminated arenaceous limestone containing fossils, 6″.

This last stratum contains a characteristic Jurassic type, *Pseudomonotis curta* Hall. This is the first or lowest known fossil bearing horizon of the Jura in this area. Any division line between the Red Beds and the Jura placed lower than this fossil bearing stratum would be an arbitrary one as there appears to be no unconformity to mark the separation. To the beds occurring above the fossiliferous horizon the term Jura-Trias is no

[1] See p. 245. [2] LOGAN: Kansas Uni. Quart., April 1900.

[3] Quoted from paper mentioned above.

longer applicable as they are unquestionably Jura. As the Red Beds represent the whole interval of time from the Carboniferous to the Jurassic so far as evidence to the contrary is concerned the term Jura-Trias alone is not applicable to them.

Continuing the section already begun we have for number

11. Arenaceous clay of a somewhat shaly nature, 6′. This layer contains near the central horizon a more highly arenaceous stratum of greenish color. It has scattered through it at different levels some rather large brown argillaceous concretions. The entire stratum seems to be unfossiliferous but it may contain *Belemnites densus* as it is often difficult to determine whether this fossil does, or does not, belong to the lower beds, since, on account of its abundance in the upper beds, it is usually scattered superficially throughout the full extent of the outcrop.

12. White sandy clay, 4′. No invertebrate fossils were found in this stratum but the remains of marine saurians belonging to the genera, *Ichthyosaurus* and *Plesiosaurus* occur in considerable abundance.

13. Purplish fossiliferous clay containing calcareous nodules, 20′. The most abundant fossil in this stratum is *Belemnites densus* which occurs distributed throughout the layer while the other fossils are confined chiefly to calcareous concretions. From these concretions the following forms were obtained: *Pinna kingi* Meek; *Cardioceras? cordiforme* M. & H.; *Belemnites densus* M. & H.; *Astericus pentacrinus* M. & H.; *Astarte packardi* White; *Pleuromya subcompressa* White; *Pseudomonotis curta* Hall; *Tancredia bulbosa* White; *Goniomya montanaensis* Meek; *Tancredia magna* Logan; *Lima lata* Logan; *Belemnites curta* Logan; *Cardinia wyomingensis* Logan and *Avicula beedei* Logan. This stratum contains also the remains of *Plesiosaurs* and *Ichthyosaurs*. It is the most abundantly fossiliferous of the entire series. It is also one of the most persistent beds, and is everywhere characterized by the great abundance of *Belemnites*.

14. Greenish colored sandstone separating into thin layers, 2′ to 4′. This stratum is very persistent, contains considerable calcareous matter, and is easily recognized on account of its

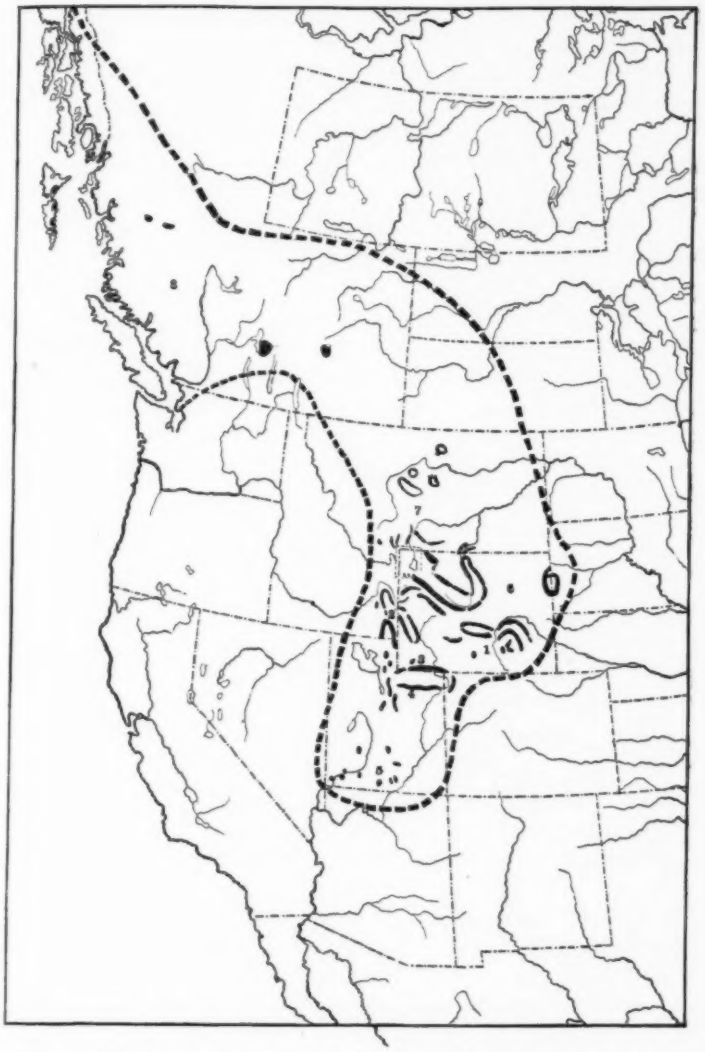

FIG. 1.—Map showing the distribution of the Jurassic formation in the interior.

uniformly greenish color. The following fossils occur in it: *Camptonectes bellistriatus* Meek; *Camptonectes extenuatus* M. & H.; *Gryphea calceola* var. *nebrascensis* M. & H.; *Ostrea strigilecula* White and *Ostrea densa* Logan.

15. Purplish clay containing considerable arenaceous inclusions, 40′. The clay contains in the upper part a thin strata of sandy limestone in which the following fossils were found: *Pentacrinus astericus* M. & H.; *Asterias dubium* White; *Pseudomonotis curta* Hall; *Avicula macronatus* M. & H.; and *Ostrea strigilecula* White.

Como beds.—The last stratum is the uppermost one, containing marine fossils and probably closes the Jura. The succeeding layer varies so much in thickness within short distances that it may represent the slightly eroded surface upon which the Como beds were deposited.

16. Fine-grained, grayish-white sandstone, 10′ to 125′. The above stratum varies much in thickness within short distances. At one point on the Dyer Ranch it has a thickness of 10′, while a few miles southeast of that point it reaches a thickness of 125′. The sandstone composing the layer is of nearly uniform color and texture. Its induration is only moderate, and it weathers into many grotesque forms. Cross-bedding is well exhibited by it in many localities.

17. Purple to greenish colored clay, 60′. This is apparently an unfossiliferous layer except in the uppermost horizon, where species of *Dinosaurs* belonging to the genera *Brontosaurus* and *Morosaurus* occur. This is the lowest fossiliferous horizon of the Como beds and the beds included between this horizon and the layer marked 15 may represent the transition from marine to non-marine conditions.

18. Sandstone, grayish to light brown, 10′ to 20′. The above sandstone presents some very interesting stratigraphical phenomena. It has at the base a layer of conglomerate about 2½′ thick. The conglomerate is composed of small argillaceous and silicious pebbles, and is not very coherent. Something like two feet of sandstone rest upon the conglomerate; the

bedding planes of the sandstone are oblique to the beds above and below. Succeeding the sandstone above is 6″ of sandstone in very thin layers, with lignitic seams along its horizontal but wavy bedding planes. The above is overlain by 4″ of conglomerate followed by 1′ of sandstone with oblique bedding planes. Overlying this layer is a thin layer of sandstone in which the bedding planes are horizontal. The remainder of the stratum is made up of sandstones with the thicknesses and bedding planes as follows: 1′ oblique; 3″ horizontal; 2′ oblique; and finally 3″ horizontal.

The beds furnished in one place the trunk of a large fossil tree and a large number of fossil cycads. Fragments of wood were found in a number of places, but cycads in only the one. Fragments of a hollow-boned *Dinosaur* were secured from one place in the horizon.

19. Drab-colored clay, 30′ to 40′. This stratum contains the remains of *Brontosaurus* and *Morosaurus*. Otherwise it appears to be unfossiliferous.

20. Fissile, brownish sandstone, 4′ to 5′. No fossils were found in this sandstone, and a most characteristic feature about it is its uniformly brown color. It seems to be moderately persistent, as it was noticed in many places in the hills.

21. Bluish-green clay, containing very small concretions, 30′. In the bone quarries of this horizon, which furnished species of *Brontosaurus*, *Morosaurus* and *Diplodocus* were found specimens of *Lioplacodes* (*Planorbis*) *veternus* Meek, and *Valvata leei* Logan. This is the lowest horizon at which any of these non-marine invertebrates were noticed. It is very probable that they will be found in the beds below as they indicate similar conditions of deposition.

22. Brown to bluish-gray arenaceous limestone, 8″ to 1′. This stratum contains the following non-marine invertebrate forms: *Unio knighti* Logan; *Unio willistoni* Logan; *Unio baileyi* Logan; *Valvata leei* Logan; and *Lioplacodes* (*Planorbis*) *veternus* Meek. Species of the same genera have been described by Meek from a similar stratum of limestone in the Black Hills.

As these occupy much the same stratigraphical position they are very likely of the same age. The *Lioplacodes* seems to be identical with that described by Meek in the Geology of the Upper Missouri.

23. Drab-colored clay, 70′. Species of the genera *Brontosaurus*, *Diplodocus*, *Morosaurus*, *Stegosaurus* and *Allosaurus* occur in this horizon. Portions of species of all these genera were found in one quarry by the Kansas University collecting party of which the writer was a member. The clay is of that quality usually designated as joint clay. It contains, in places, iron and argillaceous concretions of small size. The iron and sometimes the bones are covered with small selenite crystals.

24. Grayish-white sandstone, 50′. This layer forms a conspicuous capping for the hills, and is the highest remnant of the anticline. It breaks up into large blocks, which lie scattered along the slopes of the underlying softer beds. Its erosion and disintegration is accomplished chiefly by sapping. No fossils were found in this stratum" (Dakota?).

The maximum thickness of the Jura for this locality does not at the most exceed 100 feet. All of the fossils are found in a vertical range of but little more than half that distance, and yet the fauna includes all the characteristic species of the interior Jurassic province. The beds are heterogeneous and indicate constantly varying conditions of sedimentation.

The entire section is given in its minutest details so that an idea of the general character of the Como beds may be obtained. In many localities this formation has been included in the Jura, although the Jura is wholly marine while on the other hand the Como is wholly fresh water. On the whole the marine beds are more calcareous but there is usually at least one thin bed of limestone in the Como. The lithological characters of the beds do not always stand out so clearly that the evidence of fossils is not required to separate the beds.

Como Lake.[1]—The stratigraphical conditions of the formation at Lake Como are not essentially different from those of the

[1] LOGAN: loc. cit.

Freeze-Outs. The beds have the same lithological characteristics, being composed of sandstones, arenaceous clays, marls and impure limestones. They rest on the Red Beds and are overlain by about the same thickness of the Como (Atlantasaurus) beds. The latter formation is capped by an apparent continuation of the same quartzitic layer which forms the surface stratum in the Freeze-Outs. From this area the following species have been determined by the writer and others: *Asterias dubium; Pentacrinus astericus; Belemnites densus; Cardioceras? cordiforme; Pseudomonotis curta; Camptonectes bellistriatus; Ostrea strigilecula; Ostrea comoensis; Pinna kingi; Tancredia inornata; Pleuromya subcompressa; Astarte packardi;* and *Goniomya montanaensis.*

Rawlins Peak.—The Jurassic at this point exhibits about the same thickness and lithological characters as that of the Como area. The beds contain the following forms: *Camptonectes bellistriatus; Belemnites densus; Astarte packardi; Pseudomonotis curta; Ostrea strigilecula;* and *Pentacrinus astericus.*

Sweetwater.—In the Sweetwater Drainage area Endlich[1] gives 300 feet as the thickness of the jura at that place and states that it contains a Gryphea and a Belemnites.

East of the Wind River Range according to the same writer[2] the Jura has a thickness of 200 or 220 feet and consists at the base of dark calcareous shales, covered by beds of dark blue limestones. These are followed by yellow shales and marls with intercalations of thin sandstone layers. Yellow, pink and greenish marls close the section. The fossils obtained are species of *Belemnites, Gryphea, Rhynchonella, Lingula, Modiola, Pecten,* and others.

THE SOUTHEASTERN IDAHO AREA

In this area St. John[3] places the thickness of the Jura at 2000 feet. Since, however, only the lowermost beds are fossiliferous it is probable that the Jura should be restricted to that

[1] Ann. Rep. U. S. Geol. Surv., Vol. XI, 1877, p. 108.

[2] *Ibid.* p. 87.

[3] Ann. Rep. U. S. Geol. Surv., Vol. XI, 1877, p. 495.

horizon. The beds consist here as elsewhere of alternating beds of sandstone, shales, and limestones.

In the Lincoln Basin the following Jurassic fossils were collected: *Ostrea strigilecula; Belemnites densus; Pentacrinus, Ostrea, Gryphea, Camptonectes,* and *Pseudomonotis.*

At Meridian Ridge Peale[1] found 150 feet of bluish and gray limestones; bluish laminated limestones and bluish argillaceous shales and slates followed by 100 feet of reddish sandstone and bluish limestone containing *Pentacrinus astericus; Ostrea strigilecula; Camptonectes bellistriatus* and other forms. This thickness of 250 feet doubtless represents a conservative average for the entire district.

On the John Day (Gray) River[2] the following fossils were collected: *Pentacrinus astericus; Belemnites densus; Camptonectes bellistriatus; Gryphea, Trigonia,* and *Pleuromya;* and from another outcrop, *Pentacrinus astericus; Ostrea strigilecula,* and *Tancredia sp.* An outcrop in the Sublette Range furnished *Pentacrinus astericus* and *Camptonectes bellistriatus.*

The Jura at Bear Lake Plateau[3] contains *Pseudomonotis curta* and other forms. The fossiliferous beds consist of 90 feet of gray limestone and 80 feet of bluish-gray limestone with bands of sandstone. This group rests on 150 feet of limestone which may also be Jura but there is no faunal evidence of its age.

On Bear River in Southwestern Wyoming Meek[4] gives the following section for the Jura: "Ferruginous sandstone, in thin layers, dipping northwest about 80° below horizon, 40 feet; bluish laminated clays with, at top (left or west side), a two-foot layer of sandstone containing fragments of shells not seen in a condition to be determined, 125 feet; Clays and sandstones, below (20 feet); gray and brown pebbly sandstone above (25 feet), 45 feet; brownish and bluish clays, with some beds of white, greenish, and brown sandstone, 115 feet." From the second layer the following fossils were obtained: *Belemnites*

[1] Ann. Rep. U. S. Geol. Surv., Vol. XI, 1877, p. 536.

[2] *Ibid.* p. 544. [3] *Ibid.* p. 585.

[4] Ann. Rept. U. S. Geol. Surv., Vol. VI, 1872, p. 451.

densus, *Trigonia Quadrangularis*, and *Pleuromya weberensis?* This stratum of 125 feet is all of the section that can, with certainty, be assigned to the Jura, as the other layers are unfossiliferous.

The third and fourth layers correspond in character to the Como beds in other areas in Wyoming.

THE NORTHERN UINTA AREA

Flaming Gorge.[1]—In the Flaming Gorge the total thickness of the Jurassic is placed at 700 feet. Three hundred feet near the middle of the outcrop contains: *Camptonectes bellistriatus; Gryphea calceola; Pentacrinus astericus; Rynchonella gnathophora; Trigonia americana, Trigonia conradi; Ostrea strigilecula;* and *Belemnites densus.* In the absence of fossil evidence the portion of the outcrop lying above and below this horizon cannot with certainty be assigned to the Jura. Therefore it is possible that the three hundred feet represents the whole thickness of the Jura for this area.

South of Dead Man's Springs calcareous beds which are thought to represent the middle part of the Jura for that area contain: *Camptonectes bellistriatus; Myophoria lineata; Gryphea calceola;* and *Pentacrinus astericus.*

Vermillion Cliffs.[2]—From Vermillion Cliffs in Northwestern Colorado White determined the following Jurassic species: *Belemnites densus; Cardioceras cordiforme; Pentacrinus astericus; Rhynchonella gnathophora; Rhynchonella myrina; Ostrea strigilecula; Ostrea procumbens;* and *Modiola subimbricata.*

The limits of the Jurassic sea in a southeasterly direction do not appear to have been far from this point. Northwestern Colorado has up to this time been the only part of the state to which unquestionable Jura could be assigned.

On Sheep Creek a basal limestone yielded *Camptonectes bellistriatus; Myophoria lineata; Gryphea calceola; Pentacrinus astericus; Belemnites densus;* and specimens of *Ostrea*, *Trigonia*, and *Volsella.*

[1] KING: Geology of the 40th parallel, Vol. I, p. 290.

[2] WHITE: Geology of Northwest Colorado, U. S. Geol. Surv., Vol. XII, 1878.

THE SOUTHERN UINTA AREA

Ashley Creek.[1]—The thickness of the Jurassic beds on Ashley Creek is estimated to be about 750 feet. Of this thickness 50 feet are blue and drab colored shales and limestones carrying *Gryphea calceola, Pseudomonotis* (*Eumicrotis*) *curta* and *Belemnites densus.* This stratum corresponds to the more densely fossiliferous zone of other localities. As the vertical range of the fossils is not given it is difficult to say whether all of the 750 feet should be included in the Jura.

Near Peoria on the western end of the range a basal limestone contains *Pseudomonotis curta* and is followed by a group of shales and marls. No thicknesses are given for this area.

Wasatch Range.[2]—In Weber canyon of the Wasatch Range the Jurassic is estimated to have a total thickness of 1600 feet. The lower part which consists of yellow and bluish limestones and calcareous shales has a thickness of 600 feet. It contains the following fossils: *Cucullaea haguei; Pleuromya subcompressa; Myophoria lineata; Myophoria sp.* and *Volsella scalpra.* As the upper 1000 feet of arenaceous texture is unfossiliferous it is more than probable that it is not of Jurassic age. As the vertical range of the fossils is not given we have no means of ascertaining how much of the 600 feet may, also, belong to another period.

At the mouth of Thistle Creek in Spanish Fork Canyon the following fossils were found: *Lyosoma powelli, Camptonectes stygius* and *Pinna sp.*

THE SOUTHERN UTAH AREA

According to Dutton[3] the known Jura of Southern Utah has a thickness of from 200 to 400 feet. The formation consists of a series of calcareous and gypsiferous shales. The beds are distinctly fossiliferous and thin out toward the south, entirely disappearing in northern New Mexico and Arizona. A few fossils have been collected from a number of localities in the region.

[1] KING: Geology of the 40th Parallel, Vol. I, p. 292.

[2] KING: l. c. p. 293. [3] Geology of the High Plateaus, Utah, p. 150.

From specimens collected on the Santa Clara River two miles below Gunlock White determined the following species: *Pentacrinus astericus* M. & H.; and *Trigonia sp.* Wh.; from near Kanara: *Pentacrinus astericus* M. & H.; *Camptonectes stygius* White; *Camptonectes bellistriatus* M. & H.; from the northern part of aquarius plateau; *Camptonectes platessiformis* White; *Trigonia montanaensis* Meek and *Gervillia sp.* White; from Potato Valley, Diamond Valley, and near Gunnison: *Pentacrinus astericus* M. & H.

From the geographic distribution of the Jura in this region it appears that the Jurassic sea did not extend far south of the southern boundary of Utah. It may be assumed also that its eastern as well as its western shore lines did not extend in this region much beyond the state boundaries. From this point the eastern shore line extends farther and farther east crossing the northwest corner of Colorado thence continuing toward the northeast and including the Black Hills area.

The thinning out of the beds toward the south may be due to the presence of a low land area at the south during this epoch. A high land area should give a thick shore deposit of a coarse, clastic nature. According to the above statements, however, the beds consist of calcareous and gypsiferous shales which indicate either a somewhat remote shoreline or a low bordering land area.

THE BLACK HILLS AREA[1]

The Jurassic formation forms one of the members in the rim of sedimentary rocks which encircles the crystalline area of the Black Hills. Here as in the central and southern areas the Jura rests upon the Red beds and is overlain by the Lower Cretaceous, the Como beds. Its thickness is in the neighborhood of 200 feet. It exhibits in general about the same lithological characters that are noticeable in the formation in the Southern Wyoming area. The beds consist of sandstones, arenaceous shales and marls, and thin beds of impure fissile limestone.

Whitfield[2] has determined the following species from this

[1] JENNEY: Nineteenth Ann. Rep. U. S. Geol. Surv., p. 593.

[2] Geology of the Black Hills, 1884.

area: *Asterias dubium* Whitf.; *Pentacrinus astericus* M. & H.; *Lingula brevirostris* M. & H.; *Rhynchonella myrina* M. & H.; *Ostrea strigilecula* White; *Gryphea calceola*, var. *nebrascensis* M. & H.; *Pecten newberryi* Whitf.; *Camptonectes bellistriatus* M.; *Camptonectes extenuatus* M. & H.; *Pseudomonotis curta* Hall; *Pseudomonotis orbiculata* Whitf.; *Avicula* (*Oxytoma*) *mucronata* M. & H.; *Gervillia recta* M.; *Grammatodon inornatus* M. & H.; *Mytilus whitei* Whitf.; *Volsella* (*Modiola*) *formosa* M. & H.; *Volsella pertenius* M. & H.; *Astarte fragilis* M. & H.; *Trapezium bellefourchensis* Whitf.; *Trapezium subequalis* Whitf.; *Pleuromya newtoni* Whitf.; *Tancredia inornata* M. & H.; *Tancredia corbuliformis* Whitf.; *Tancredia bulbosa* Whitf.; *Tancredia postica* Whitf; *Tancredia warrenana* M. & H.; *Dosina jurassica* Whitf.; *Psammobia? prematura* Whitf.; *Thracia? sublevis* M. & H.; *Neaera longirostra* Whitf.; *Saxicava jurassica* Whitf.; *Quenstedioceras* (*Cardioceras*) *cordiforme* M. & H.; and *Belemnites densus* M. & H.

In the Big Horn Basin region Eldridge[1] discusses the Jura as follows: "This, so far as the evidence obtained indicates, is, within the region under examination, wholly of marine origin. The thickness is between 400 and 600 feet, which is approximately maintained over the entire area of exposure. Shales constitute the mass of the formation in which from base to summit occur thin beds of sandstone and fossiliferous limestone of types characteristic of the Jura in the Rocky Mountain region. Gray is the predominating color of the shales, but throughout the formation red, purple, yellow, slate, and pink, in greater or less intensity, may be observed. At a number of localities a considerable amount of siliceous matter appears, in occurrence suggesting the action of hot waters.

"The sandstones are of slight importance. They are chiefly gray with a slight greenish tint. The lower beds, however, are red, shaly and transitional from the Trias, while near the summit are two of greater thickness, which, but for their tint and the overlying typical Jura shales, might be confounded with the Dakota.

[1] Bull. U. S. Geol. Surv. No. 119.

"The limestones are nearly all fossiliferous, and of the drab color peculiar to the Jura in the west. In thickness they vary from a few inches to 15 feet. Three or four in the lower 100 feet and one or two in the upper third of the formation are especially prominent."

The formation is said to be overlain by the Dakota sandstone. If this so-called Dakota sandstone is at the same horizon that it is in the Freeze-Out Hills, and it seems from the description very probable that it is, then the Jura so-called must include the Como beds. The description of the upper part of the formation fits the Como, while the lower part with its fossiliferous limestones is very characteristic of the Jura both north and south of this area. The Como or its stratigraphic equivalent is recognized both north and south of this region and there appears no good reason for its absence in this area.

THE MONTANA AREA

Castle Mountain.[1]—The Jurassic formation in this area is less than one half the average thickness for the interior. Its maximum thickness is only ninety feet. The formation consists of a basal sandstone overlain by a dense white limestone. The limestone layer is highly fossiliferous and contains the following well-known Jurassic forms: *Astarte packardi; Trigonia montanaensis; Pinna kingi; Pholadomya kingi; Ostrea sp.; Camptonectes extenuatus; and Gervillia montanaensis.*

The Jura of this locality rests upon upon the Carboniferous and the Red Beds are not represented. It is the belief of the writers that the beds are wanting altogether in Montana, or at least but sparingly represented.

Little Rocky Mountains.[2]—The total thickness of the Jura for this region is placed at 100 feet. The beds consist of shaly gray limestones which change to impure, marly shales and argillaceous limestones. They rest on limestones of Carboniferous age and the Red Beds are again absent.

[1] WEED and PIRSSON, Bull. 139, U. S. Geol. Surv., 1896.

[2] WEED and PIRSSON, JOUR. GEOL., Vol. IV, 1896.

The Jurassic limestones contain the following species: *Astarte meeki; Belemnites densus; Pleuromya subcompressa; Gryphea calceola*, var. *nebrascensis;* and a fragment of an undetermined Ammonite.

This is one of the most northerly areas from which Jura has been recorded for Montana. If the formation is present in the Bear Paw Mountains which lie to the northwest of this area it has not been differentiated.

Three Forks.[1]—The Jura has a thickness in this area of from 300 to 400 feet. The lower beds rest on a basal quartzite and consist of argillaceous limestones which carry characteristic Jurassic fossils. The middle and upper beds are more arenaceous than the lower beds and are non-fossiliferous. Under such conditions it is very questionable whether they should be assigned to the Jura. It is very probable that the thickness of the Jura in this area conforms more nearly to that assigned to it in other areas of Montana.

Livingston.[2]—The Jurassic formation of the Livingston area has a thickness estimated at 400 feet. It consists at the base of a massive, cross-bedded, ripple-marked sandstone. This sandstone is overlain by a layer of impure fossiliferous limestone containing *Pleuromya subcompressa* M. The limestone is followed by a bed of arenaceous limestones containing shell fragments. Since the lower layer is non-fossiliferous it may or may not represent a part of the Jura, but there is the possibility of an overestimation of thickness here as well as in the Three Forks area.

Although the thicknesses given for the Three Forks and Livingston area are not extremely large, yet they are nearly double that given for the other Montana areas. But as has been pointed out, this lack of harmony may be due to the inclusion of beds belonging to other formations. If the faunal relations are not carefully worked out in connection with the stratigraphy errors are likely to occur either in the direction of the overlying

[1] PEALE, U. S. Geol. Surv., Three Forks Folio, 1896.

[2] IDDINGS and WEED, U. S. Geol. Surv., Livingston Folio, 1894.

or the underlying beds. For the Jura in many localities, so far as physical characters are concerned, grades almost imperceptively into the Red Beds below and the Como above.

Judith Mountains.[1]—Weed and Pirsson give the following section as representing the Jura in the Judith Mountains. The base is separated from the Carboniferous by a sheet of porphyry.

		Feet.
1.	Limestone, dark gray, laminated, and shaly	10
2.	Limestone, blue to gray in color, hard in texture, and carrying Ostreæ in 3 to 5-foot beds, separated by thinner platy beds	12
3.	No exposure	25
4.	Shaly, argillaceous, impure limestone, dove colored, weathering buff on joint faces and of typical Jurassic aspect	5
5.	Shaly beds, seldom exposed, carrying oolitic limestone. Green or sandy limestone of drab color	15
6.	Rough weathering limestone, fine grained, cross-bedded and fissile, carrying fossils	5
7.	Sandy limestone like that above, but irregularly bedded and resembling sandstone; granular and saccharoidal in texture, carries shell fragments	4
8.	Irregularly platy, earthy-brown, gray limestone carrying shell remains of *Gryphea* and *Ostrea*, weathering dark brown, rarely granular	6
9.	Marly shales and limestone, dove colored, carrying fossils noted in following pages, seldom exposed, *Gryphea* most abundant here	30
10.	No exposure, but débris of sandstone	60
11.	Ellis sandstone, variable, buff, platy sand rock; pink blotched at base with occasional shells; cross-bedded purple-brown outcrop. It is at the top a limestone full of black and white quartz sand grains and forms a dark brown ridge	12

This section gives the total thickness of the Jura for this region at 184 feet, which is nearly double that of the Little Rocky and Castle Mountain areas.

The fossils collected from the horizon mentioned above are: *Ostrea strigilecula* White; *Gryphea calceola* var. *nebrascensis* M. & H.; *Modiola subimbricata* M.; *Cucullaea haguei* M.; *Pleuromya subcompressa* M.

[1] WEED and PIRSSON, Eighteenth Ann. Rept., U. S. Geol. Surv., III, p. 445.

Yellowstone Park.[1]—The thickness of the formation for this area is placed at 200 feet. It consists of sandstones, marls, limestones, and clays, and contains, according to Stanton,[2] the following species: *Pentacrinus astericus* M. & H.; *Rhynchonella myrina* Hall & Whitf.; *Rynchonella gnathophora* M.; *Ostrea strigilecula* White; *Ostrea engelmani* M.; *Gryphea planoconvexa* Whitf.; *Gryphea calceola* var. *nebrascensis* M. & H.; *Lima cinnabarensis* Stan.; *Camptonectes bellistriatus* M.; *Camptonectes bellistriatus* var. *distans* Stanton; *Camptonectes pertenuistriatus* Hall & Whitf.; *Camptonectes platessiformis* White; *Avicula* (*Oxytoma*) *Wyomingensis* Stan.; *Pseudomonotis Curta* (Hall)?; *Gervillia montanaensis* M.; *Gervillia* sp. Stan.; *Modiola subimbricata* Meek; *Pinna kingi* M.; *Cucullaea haguei* M.; *Trigonia americana* M.; *Trigonia elegantissima* M.; *Trigonia montanaensis* M.; *Astarte meeki* Stan.; *Astarte* sp. Stanton; *Tancredia? knowltoni* Stan.; *Protocardia shumardi* M. & H.; *Cyprina? Cinnabarensis* Stanton; *Cyprina? iddingsi* Stanton; *Cypricardia? haguei* Stanton; *Pholadomya kingi* M.; *Pholadomya inaequiplicata* Stan.; *Homomya gallatinensis* Stan.; *Pleuromya subcompressa* M.; *Thracia weedi* Stanton; *Thracia? montanaensis* (Meek)?; *Anatina* (*Cercomya*) *punctata* Stan.; *Anatina* (*Cercomya*) sp. Stan.; *Neritina wyomingensis* Stan.; *Lyosoma powelli* White; *Turitella* sp. Stan.; *Natica* sp. Stan.; *Oppelia?* sp. Stan.; *Perispinctes* sp. Stan.; and *Belemnites densus* Meek and Hayden.

THE CANADIAN AREA

In the Queen Charlotte Islands Whiteaves[3] noted the occurrence of the following species, which are common to the Jura of the Interior: *Pleuromya subcompressa* Mk.; *Astarte packardi* White; *Avicula* (*Oxytoma*) *mucronata* Mk.; *Gryphea calceola* var. *nebrascensis* M. & H.; *Lyosoma powelli* White; *Belemnites densus* M. & H.; *Belemnites skidgatensis* Whiteav.; *Grammatodon inornatus* Whiteav.; *Modiola subimbricata* Mk.; and *Camptonectes extenuatus* Mk.

Although Whiteaves recognized the interior affinity of these forms, he was inclined to put both groups into the Cretaceous

[1] U. S. Geol. Surv., Yellowstone Park Folio, 1896.

[2] U. S. Geol. Surv., Yellowstone Park Monograph, XXXII, p. 601, 1899.

[3] Geol. Surv., Canada, Mesozoic Fossils, Vol. I.

rather than the Jura. But the Jurassic age of these beds is now sufficiently well established not to require further discussion.

Not only is this fauna represented in the islands just mentioned, but it occurs also on the continent at some considerable distance inland. From fossils collected by G. M. Dawson on the Iltasyouco River in British Columbia about Parallel 53° and Longitude 126° West, Whiteaves[1] recognized the following species: *Pleuromya subcompressa* Mk.; *Pleuromya lævigata* Whiteav.; *Astarte packardi* White; *Trigonia dawsoni* Whiteav.; *Modiola formosa* M. & H.; *Gervillea montanaensis* Mk.; *Gryphea calceola* var. *nebrascensis* M. & H.; *Grammatodon inornatus* Whiteav.; *Oleostephanus loganianus* Whiteav.

These fossils were found in the felsites and porphyrites of the metamorphic rocks lying east of the Coast Range. They contain species common to both the Queen Charlotte and the Interior faunas.

From fossils collected by G. M. Dawson at Nicola Lake in British Columbia Hyatt[2] determined the Jurassic age of certain beds in that region lying above the Triassic. The fossils collected are: *Rhynchonella gnathophoria?*; *Pecten acutiplicatus* Gabb; *Entolium* sp. Hyatt; *Lima parva* Hyatt.

Just north of Parallel 51°, near the east end of Devil's Lake, which is situated on the eastern border of the Front Range of the Rockies, McConnell[3] found an outlier of Jurassic which contained the following fossils: *Avicula* (*Oxytoma*) *mucronata*; *Trigonia intermedia*; *Trigonarca tumida*; *Terebratula*, *Ostrea*, *Camptonectes*, *Lima*, *Cyprina*, *Ammonites*, and *Belemnites*. This locality serves as a connecting link between the Montana area and the localities to the west, as it is situated midway between the two. The above-named group of fossils contains one species and a number of genera common to the Interior and the Pacific Coast deposits.

[1] Loc. cit.

[2] Rept. of Geol. Surv., Canada, 1894, p. 51.

[3] Rept. of Geol. Surv. Canada, 1896, p. 17d.

THE ALEUTIAN AREA

Grewingk[1] was the first to announce the occurrence of beds of Jurassic age in Alaska. These beds were discovered at different places along the Alaskan Peninsula and the Aleutian Islands. From the distribution of these beds as mapped by Grewingk the Alaskan Peninsula and the Aleutian Islands must have been under water during Jurassic times.

In 1872 Eichwald[2] described an assemblage of fossils collected from these same beds and correlated them with the Northern Russia beds of the same age, but put both formations in the Lower Cretaceous. Some fossils were collected from the same region by Dall in 1883. These forms were described by White,[3] who after making a study of them and comparing them with Eichwald's descriptions, decided that the latter was wrong in his assignment of the beds to the Cretaceous. He found them to be closely allied to the Jurassic of Northern Russia. One species, *Aucella concentrica* Fisher, he considers either identical or only a variety of the Eurasian Jurassic form of that name.

Hyatt,[4] in speaking of these deposits, says: "The fauna of the Black Hills, acknowledged to be Jurassic by everyone but Whiteaves, is in part apparently synchronous with that of the Aleutian Islands and Alaska, as described by Eichwald and Grewingk."

The position of these beds and the relation of the fauna with the northern Eurasian fauna points clearly to an Arctic-Pacific connection by way of the Bering waters during this epoch. Moreover we now have an almost continuous faunal record extending from Alaska to southern Utah.

Conclusions.—An examination of the above sections will show that the thickness of the Jura in the interior is not very great. An average of ten localities gives a thickness of but little over

[1] Russian Kaiserl. Mineral Gesell., 1848–9.

[2] Geognostisch-Paleontologische Bemerkungen über die Halbinsel Mangischlak und die Aleutschen Insel.

[3] Bull. U. S. Geol. Surv. No. 4, 1884.

[4] Bull. Geol. Soc. Am., Vol. V, 1894, p. 409.

two hundred feet. In fourteen localities the thickness is under four hundred feet. These localities are scattered throughout the length and breadth of the interior province. In all the areas for which greater thicknesses have been recorded there are none in which the entire thickness could, without question, be assigned to the Jura.

The lithological character of the beds is much the same for all areas. The formation consists everywhere of essentially the same group of arenaceous clays, shaly marls, impure limestones and sandstones. The order of succession of the beds implies ever changing conditions of sedimentation. Thin beds of sandstone are overlain by thin beds of fossilferous clays, marls, or limestones; and these in turn are followed by another similar group.

The absence of any considerable thickness of limestone over a large area indicates that for no great period of time were the waters of the sea entirely free from clastic sediments. The presence of cross-bedded sandstone and ripple-marked layers at different horizons, the almost universal presence of *Ostrea* and other shallow water forms, together with the stratigraphic and lithologic characters just mentioned prove that the waters of the sea were not of great depth; that the sea was not of the abysmal type. It was not a sea comparable in depth to the Mediterranean but was a shallow epicontinental sea. From the geographic distribution of the known Jurassic the outlines of this sea were as indicated on the map[1] accompanying this paper.

From the character and extent of the sea it may be assumed that no extensive epeirogenic movement was necessary for its inauguration, providing the antecedent topographic conditions were favorable. In the northern part of the area there is evidence that a considerable period of erosion preceded the Jura, as the Red Beds are absent and the Jura rests on the Carboniferous. This period of erosion may have been sufficient to reduce the land area to approximate base level in which case a very slight warping would have been sufficient to let the waters of this

[1] See p. 245.

shallow sea in upon the continent. A very slight increase in the capacity of the ocean basin would suffice to draw the water off the continent at the close of the period. The increase in the capacity of the ocean may have been accomplished by a slight settling of the oceanic segment. The withdrawal of the waters of the epicontinental sea was doubtless the initial step in the movement which ended in the elevation of the Sierra Nevada Mountains; for the withdrawal took place at the close of the Oxfordian stage or during the Corallian and according to Diller[1] the orogenic movement which produced the Sierra Nevada and Klamath Mountains took place at the close of the Corallian. If these interpretations be logical ones we may assume that it required little or no bodily movement of the continent to produced either the inauguration of the Jurassic sea or its withdrawal from the continent. It may be asserted further that there is nothing connected with its history which is inimical to the doctrine that the continent had in general its present outline during Jurassic times and that the waters of the submerged portions were of an epicontinental nature.

The writer's study of the faunal conditions in the field has led him to the opinion that only one fauna is to be recognized in the Jurassic deposits of the interior province. A comparison of the fossils collected from the different areas just discussed serves to strengthen the opinion. Everywhere the formation is characterized by about the same group of fossils, of which the more characteristic ones are: *Pentacrinus astericus*, *Belemnites densus*, *Camptonectes bellistriatus*, *Pseudomonotis curta* and *Cardioceras cordiforme*. These forms all existed contemporaneously.

Stanton[2] discusses the view expressed by Hyatt[3] that more than one Jurassic fauna may be represented in the Interior and arrived at the following conclusion: "the stratigraphic relations and the geographic distribution of the marine Jurassic of the Rocky Mountain region are in favor of the idea that all of these deposits were made contemporaneously in a single sea."

[1] Bull. Geol. Soc. Am. Vol. IV, p. 228.

[2] U. S. Geol. Surv. Yellowstone Park Monograph XXXII, 1899, pp. 602–604.

[3] Bull. Geol. Soc. Am. Vol. III, 1892, pp. 409–410.

This fauna according to Hyatt belongs to the Oxfordian stage of the Upper Jura or Malm. In the Taylorville series of California he recognized the Callovian, the Oxfordian and the Corallian stages of the Upper Jura. But as has been stated above none but the middle stage has been recognized in the Interior.

Relation of the interior fauna to the northern eurasian fauna.— The discovery of beds of Jurassic age in the interior was first announced by Meek[1] in 1858. In correlating these beds with the Jura of the Old World he says: "The organic remains found in these series present, both individually and as a group, very close affinities to those in the Jurassic epoch in the Old World; so close indeed, that in some instances, after the most careful comparisons with figures and descriptions, we are left in doubt whether they should be regarded as distinct species, or as varities of well-known European Jurassic forms. Among those so closely allied to foreign Jurassic species may be mentioned an Ammonite we have described under the name of *Ammonites cordiformis* which we now regard as probably identical with *Ammonites cordatus* of Sowerby; a *Gryphea* we have been only able to distinguish as a variety from *G. calceola* Quenstedt; a *Pecten*, scarcely distinguishable from *Pecten lens* Sowerby; a *Modiola*, very closely allied to *M. cancellata*, of Goldfuss; a *Belemnite*, agreeing very well with *B. excentricus*."

Since the publication of the above statements by Meek the paleontology of the European Jura has been more completely worked out and some of the faunas, particularly that of northern Russia, are found to have still closer affinities to the American interior fauna. The Jurassic faunas of America have also received many additions at the hands of the American paleontologists Gabb, Hyatt, Meek, Smith, Stanton, White, Whiteaves, and Whitfield. All of these studies have tended to strengthen the opinion just expressed.

The following comparison of forms which are so closely allied as to deserve, in many cases, to be called varieties of the same species will serve to show the close affinity of the interior

[1] Geological Report of the Exploration of the Yellowstone and Missouri Rivers.

American fauna to the fauna of northern Eurasia: *Belemnites panderanus* d'Orb. and *Belemnites densus* Mk.; *Astarte duboisianus* d'Orb. and *Astarte pakardi* White; *Avicula volgensis* d'O. and *Avicula mucronata* Mk.; *Pentacrinus scalaris* Goldf. and *Pentacrinus astericus* M. & H.; *Goniomya dubois* d'Orb. and *Goniomya montanaensis* Mk.; *Gryphea calceola*, Quen. and *Gryphea caceola* var. *nebrascensis* Mk.; *Cardioceras cordatus* Sow. and *Cardioceras cordiforme* Mk. The faunas taken as a whole exhibit the close relationship in a much more forcible manner than the comparison of a few species.

This northern Eurasian, or *Cardioceras* fauna is thought to have had its origin on the northern shores of the Eurasian continent, and to have migrated from there to American waters. This assumption is based on the sudden appearance of the fauna in America and its close affinities with older Eurasian faunas. The present geographic distribution of the fauna indicates a northern connection.

A later Jurassic fauna, the *Aucella* fauna, probably had its origin in the north and migrated to Pacific waters. This fauna, however, did not reach the interior province of America as the waters of the epicontinental sea had been withdrawn before its appearance. This later migration extended along the Pacific coast as far south as Mexico.

Both of the faunas just mentioned belong to the Upper Jura, but the Lias and Middle Jura are also represented in the Californian province. The Upper Jura, however, represents the maximum encroachment of the ocean on the American continent as well as on the Eurasian continent. It also marks the maximum expansion of marine life, induced doubtless by increased feeding grounds.

Connection of the sea with the ocean.—The question as to where the interior sea had its connection, or connections, with the ocean is important in estimating the extent of the submergence, That the sea had a Pacific Ocean connection there seems no longer room for doubt. The occurrence in the Queen Charlotte fauna of so many species common to the interior places the

question beyond controversy. That there was communication between the Arctic and the Pacific is supported by the presence of Arctic species in the Pacific fauna. From the distribution of the Jurassic sediments as given in the preceding pages it may be asserted with a measurable degree of confidence that the connection between these two bodies of water was during Jurassic times as it is today by way of the Bering waters. As the presence of Jurassic deposits on the Alaskan Peninsula and the Aleutian Islands testify to the submergence of those areas, it may be assumed that communication between the two oceans was somewhat freer than at present.

The question which is now brought to mind is whether the interior sea had any other connection with the ocean. The character of the fauna excludes any hypothesis favoring a southern connection either with the Gulf of Mexico or the Pacific. If there had been such a connection a southern facies would be expressed in its fauna. Such evidence is entirely absent. The evidence against any other Arctic connection is largely negative, but as such is measurably strong. The investigations of American and Canadian geologists have failed to bring to light any Jurassic deposits in the North aside from those already described, although approximately the whole area where we should expect to find them has been gone over.

McConnell,[1] who made geological investigations in Athabasca and along the Finlay and Porcupine Rivers, found Cretaceous beds resting on Devonian and Carboniferous strata. The interval of time which elapsed between the Carboniferous and the Lower Cretaceous is not represented in this region.

Spurr[2] found the same conditions to obtain for the Upper Yukon region of Alaska and the neighboring British territory. The Lower Cretaceous rests on Devonian or Carboniferous rocks. As before stated this evidence is merely negative. Jurassic rocks may have been deposited and afterwards cut away. But,

[1] Geol. Survey of Canada, Vols. V and VII.

[2] Geol. of the Yukon Gold District, U. S. Geol. Surv., Seventeenth Ann. Rept., 1897.

in that case, we should expect to find remnants of the former beds unless it be assumed that a long interval of time preceded the deposition of the Lower Cretaceous. Paleontologic and stratigraphic evidence is not in harmony with this assumption. The Lower Cretaceous beds of California which are but slightly unconformable with the Upper Jurassic, having a closely related fauna, are correlated with the Lower Cretaceous of the region under discussion.[1]

In many places in the interior region the Lower Cretaceous rests conformably on the Jurassic. This fact has been fully brought out in the preceding pages. It cannot be affirmed that the interior sea first had its connection with the Arctic and then gradually spread its waters farther and farther west until it united with the Pacific. For if this were true we should find in the interior first a fauna composed wholly of northern species, followed later by a fauna containing both Arctic and Pacific types. But no such conditions find expression in the faunal relations of the interior. Only one fauna exists in the interior.

There exists at present no evidence which will support the view held by Neumayr,[2] that the whole of Alaska and all of that portion of British America lying north of the interior Jurassic area of the United States was submerged during this epoch. All that can be asserted positively is that the Aleutian Islands and Alaskan Peninsula, in part at least, a narrow margin along the Alaskan coast and a wider area in California and Mexico was under water, while an arm of the Pacific extended in upon the continent from the region of the Queen Charlotte Islands.[3]

Lack of communication between the provinces.—The Jura of California and Nevada contains a fauna which is very different from that of the interior, although the faunas are contemporaneous. To explain the difference between the two faunas Neumayr assumed that that they belonged to two distinct climatic provinces. He assumed that the interior fauna was a Boreal fauna

[1] Spurr, l. c., p. 183.

[2] See map p. 267, copied from Erdgeschichte, p. 336.

[3] See map p. 245.

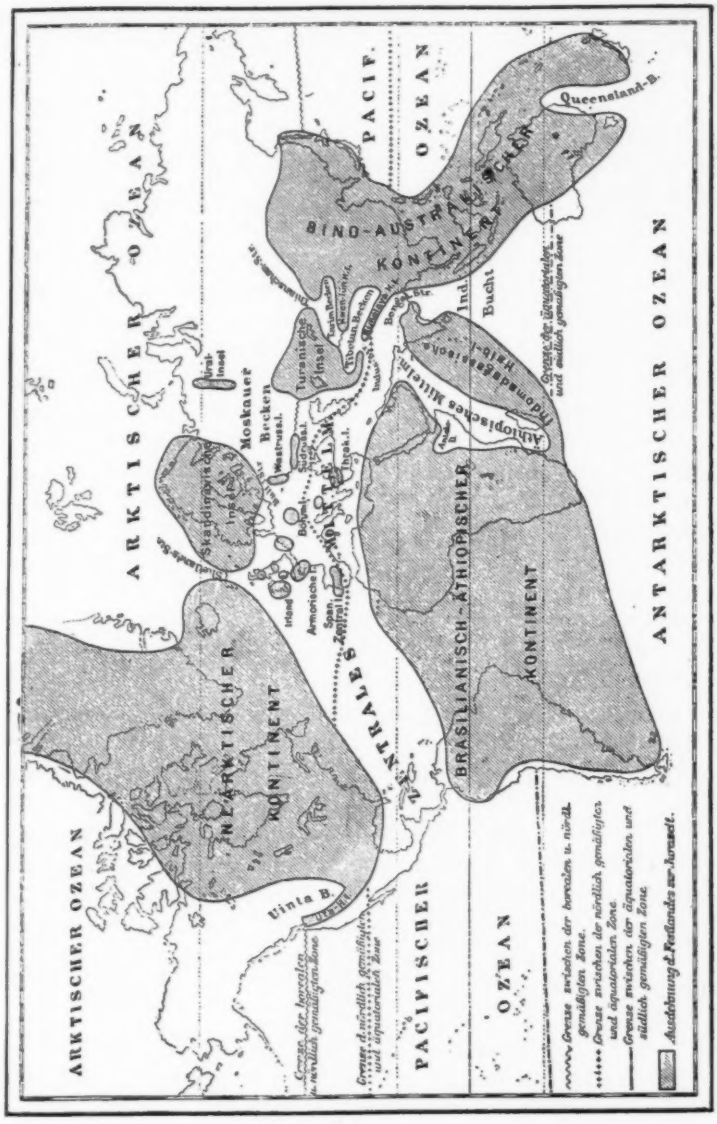
ARKTISCHER OZEAN
ARKTISCHER OZEAN
PACIF. OZEAN
BIND-AUSTRALISCHER KONTINENT
Queensland-B.
Indische Bucht
Turanische Insel
Moskauer Becken
Skandinavische Inselland
Uinta B.
NEARKTISCHER KONTINENT
Grenze der borealen u. nördlich gemäßigten Zone
Grenze nördlich gemäßigter und equatorialer Zone
PACIFISCHER OZEAN
ZENTRALES
BRASILIANISCH-ÄTHIOPISCHER KONTINENT
Äthiopisches Mittelmeer
Thomasbaai
Halbinsel
Grenze der äquatorialen und südlich gemäßigten Zone
ANTARKTISCHER OZEAN
Grenze zwischen der borealen u. nördl. gemäßigten Zone.
Grenze zwischen der nördlich gemäßigten und equatorialen Zone.
Grenze zwischen der equatorialen und südlich gemäßigten Zone.
Ausdehnung d. Festlandes zur Jurazeit.

FIG. 2.

which lived in an arm of the Arctic Ocean, and that the Californian fauna belonged to another climatic province, the north temperate.

In a recent discussion of the subject Ortman[1] has shown very conclusively that the faunal differences of Jurassic times, so far as the Eurasian continent is concerned, were not due to climatic zones. The distribution of the interior or Cardioceras fauna favors this view for the North American continent, The Cardioceras fauna is found distributed through a range of latitude extending from 37° to 80° north. Its southernmost extension is not as placed by Neumayr in the neighborhood of 46°, but is at least as far south as 37°, and is found in approximately the same latitude as the Californian province. Moreover, the later (for the American region) Jurassic fauna, the Aucella, has been reported from Mexico.[2] The Aucella fauna also had its origin in northern Eurasian waters. Its geographic range was from 80° north to 25° north. This means an extension of Neumayr's Boreal province to within 25° degrees of the equator! The great geographical range of this fauna indicates that there was little or no climatic restriction to its migration. In so far as the evidence can be deduced from the geographic distribution of the American Jurassic faunas the climate of the period may be said to have been more uniform than it is today.

The above facts are perhaps sufficient to show the weakness of the climatic-zone hypothesis. It now remains to suggest an alternative line of investigation. In seeking for the causes for the want of communication between the provinces it may be possible to draw some analogy from the faunal and topographic conditions as they exist today on the Pacific coast. There are at present on the Pacific coast, according to Fischer,[3] two faunal provinces, the Aleutian, corresponding in position to the Queen Charlotte of Jurassic times, and the Californian, corresponding to the Jurassic province of the same name. The line

[1] Am. Jour. Sci. Vol. I, 1896, p. 257.

[2] Nitikin, Neus Jahrb. Min. Geol. Pal., 1890, II, p. 273.

[3] Manuel Conchologie.

separating these two provinces is placed in the vicinity of Vancouver Island. The faunal interrelations of these two provinces are as follows: Of seventy-eight genera occurring in the two provinces nine are common to both ; of one hundred and four species six are common to both ; and of ten circumpolar species which have reached Vancouver Island and Puget Sound only four occur in California, and but one in Lower California. From these conditions it will be seen that communication between the two provinces is almost, if not quite, as thoroughly prohibited now as it was during Jurassic times. The question which now arises is what restricts communication between the two provinces at present? It cannot be said to be due to climate alone, for why in that case should the circumpolar species be found so far south? And why should they all be found in Puget Sound and not be found farther south? This seems to be an exception to the general rule that the climatic provinces of the present time are connected by transition zones. For the line of demarcation is moderately sharp.

Aside from the matter of climate there are two physiographic conditions which may be operative. The first of these lies in the extreme narrowness of the sumerged shelf lying to the north and west of Puget Sound. This shelf teeming with organisms already well established offers small inducement to migratory forms. And only the more hardy forms would be likely to survive the struggle for existence under such circumstances as are here postulated. Thus the change of species from one province to the other is necessarily slow.

There are good reasons for believing that throughout the Mesozoic era these topographic conditions of the Puget Sound region were much as they are at present. During the Horsetown epoch the Pacific shoreline, although it lay a considerable distance east of the present shoreline in California and Oregon, very closely approximated it in the Puget Sound area. The Chico also had a very restricted epicontinental area at that point as the Chico shoreline extended only to the eastern coast of Puget Sound. In California and Oregon, however, its eastward

extension was far beyond that of the Horsetown.[1] The Jurassic beds do not occur in the Puget Sound region, and as they underlie the Horsetown elswhere, it is evident that the Jurassic shoreline at this point must have been at least as far west as the present shoreline.

A second cause for the lack of communication between the two provinces may lie in the position of the ocean currents. The Californian currents coming from the west along a line lying between the Queen Charlotte Islands and the island of Vancouver turns south at some notable distance from the coast, and after passing Vancouver bears toward the coast and flows on along the Californian province. The North Pacific current which flows east closely parallel to the Californian bears northward before reaching the Queen Charlotte Islands. Neither of these currents, since they do not cross the line separating the two provinces, is effective in establishing communication by carrying embryonic or larval forms which might under different circumstances be brought within their reach. This same distribution of ocean currents probably held during Jurassic times, as in general, the large land masses in this region, at least, had their present distribution.

The attractive feeding ground furnished by the epicontinental sea doubtless exerted its influence to prevent southern migration. When later the waters were drawn off the continent the accumulation of the great numbers of organisms on the coast may have been sufficient to force the migration southward. Or perhaps the interval of time was sufficiently long for some of these northern species to have forced their way into the Californian province during later Jurassic time. In either case we would have in the Upper Jurassic faunas of California a northern element, and this seems a well-established fact. Nevertheless, since this Upper Jurassic fauna has been reported from Mexico it is evident that communication was freer between the two provinces after the withdrawal of the waters of the epicontinental sea. And it is very likely that the movement which caused

[1] See map p. 271.

FIG. 3.—Map showing the approximate position of the Chico (C) and Horsetown (H) Shore lines (after Diller and Stanton).

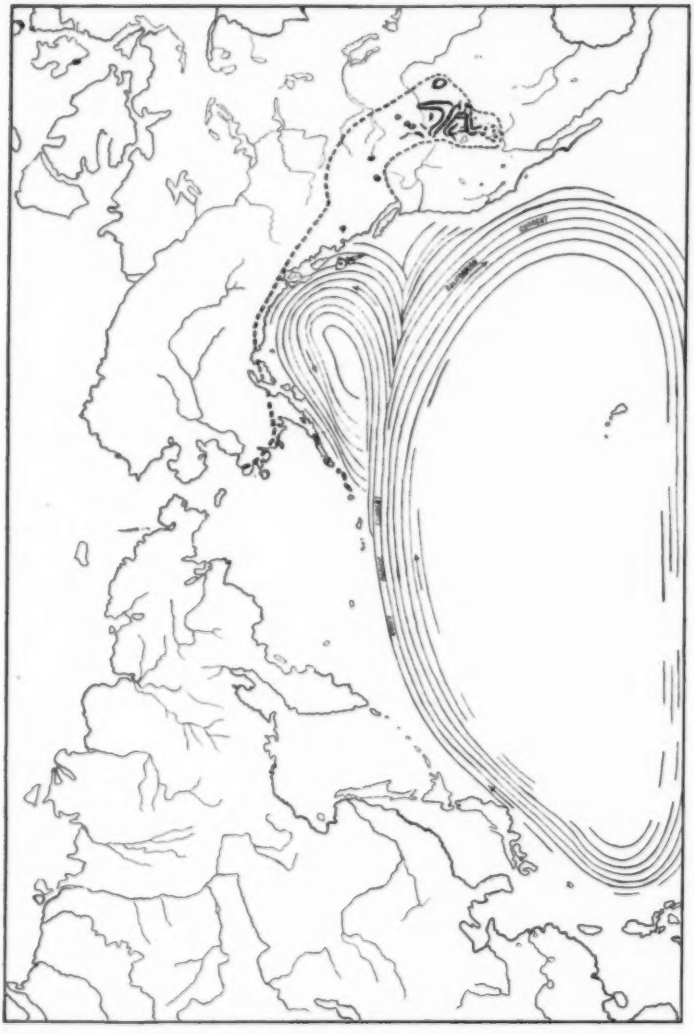

FIG. 4.—Map showing the position of the North Pacific Currents and the approximate outline of the Jurassic Sea.

the withdrawal also slightly depressed the barrier between the provinces.

Final conclusions.—It now remains to state briefly, in review, the conclusions to which the lines of investigation have led. They are as follows: 1. The Jurassic formation of the interior province of North America was not deposited in a body of water of even moderate oceanic depth, but in a shallow epicontinental sea.

2. This sea had but one connection with the ocean and that connection was with the North Pacific in the Queen Charlotte Island region; in general the outlines of the sea were as indicated on the map accompanying this article.

3. There was a connection, during this epoch, between the Arctic and Pacific by way of the Bering waters, and by this means circumpolar and Pacific faunal communication was established.

4. The Jurassic deposits of the interior contain but one fauna and if more than one period of time is represented it is not indicated by a change in the fauna.

5. The fauna of the interior is closely allied to the Cardioceras fauna of northern Eurasia.

6. Physiographic rather than climatic condition restricted communication between the Californian and interior provinces.

7. Nothing connected with the history of this Jurassic sea or its faunal relations is inimical to the view that during this epoch the North American continent had, in general, its present outline.

8. The geographic distribution of land and water, as postulated by Neumayr for this period, is not supported by the facts, in so far as the North American Jura is concerned.

W. N. Logan.

EDITORIAL

GEOLOGISTS heartily participate in the satisfaction which astronomers justly feel over the great mass of accurate data which favorable conditions and their own zeal and skill enabled them to gather from the recent solar eclipse. Geologists offer their cordial felicitations not only as fellow scientists rejoicing in the common advancement of science for its own sake, and for its influence on the world, but because they are themselves concerned in the solution of the solar problems. Especially are they interested in those questions of the sun's constitution and internal activities which bear upon his sources of heat, present, past, and future; for these vitally touch the limitations of geologic history. It is impossible, therefore, for historical geologists to be indifferent to the results of any investigation that promises to throw light upon the thermal endurance of the sun.

The central subject of interest in the recent observations, the constitution of the corona, may seem quite remote from any geologic relationship, but, as in so many other cases in the history of science, light upon dark problems may come from an unexpected source. It is not beyond the limits of speculation to conceive that the corona may prove to be the very phenomenon that will point the way to a revised estimate of the thermal possibilities of the sun and thus to a revised measure of its past duration and of the age of the earth as one of its dependencies. Some hint of the possibilities may be found in the logical sequences of one of the alternative working hypotheses relative to the coronal nature. If the conception that it is formed of extremely attenuated matter driven away at great velocities, after the analogy of the tails of comets, should be substantiated, it will necessarily be followed by the problem of the origin of such attenuated matter. In the case of comets such supposed matter may be assumed to be simply an accessory constituent brought in from distant space and developed by approach to the sun — and soon exhausted in the case of captured comets — but such a

hypothesis does not seem well fitted to the sun itself in this late stage of its history. The alternative conjecture that the attenuated form of matter is developed in the sun by the extraordinary agencies operative there must obviously be entertained until disproved, and the recent investigations of J. J. Thompson and others with reference to the extremely attenuated ionization of terrestrial gases under certain conditions render such a hypothesis less highly improbable than it would have seemed under the dominance of the inherited doctrine of the indivisibility of the atom.

A speculation which involves the notion of the divisibility of the atom involves also that of the divisibility of the internal energies of the atom and their possible transformation into radiant energy, and hence a possible source of heat of unknown and, at present, quite incalculable amount.

So too, a speculation which assumes that the corona is radiated matter involves also the conception of loss of sun's substance if the velocity of radiation be as high as that attributed to the conjectural matter of comets' tails; and if this loss of matter in the course of great secular periods becomes appreciable, it may require a reconsideration of the data upon which estimates of the sun's heat are based and also of a revised consideration of the former distances of the planets.

Now such an attenuated chain of hypotheses, each dependent on an antecedent hypothesis of uncertain verity, may be altogether too unsubstantial to have any appreciable value of the positive sort, other than as the antecedent of investigation, but it may have the negative virtue of helping to keep open the question of the sum total of the sources of the sun's heat and its possible duration in the past and the future. And so possibly may also the logical sequences of the alternative coronal hypotheses. The Helmholtzian theory assigns a source of heat of such competency that it cannot be proved not to be the sole essential cause by any measurements of the sun that can be made now, or probably in the near future, and hence it satisfies the immediate demands of astronomical science, however inadequate it may be to meet the natural interpretations of geological and biological data;

but it may be conjectured that when the history of the stellar system shall become as serious and substantial a subject of study as the history of the earth now is, astronomers will find at least as great need for long lapses of time and for the secular endurance of thermal states as do the geologists and biologists.

Meanwhile all solar inquiries are subjects of acute interest in common and the achievements of May 28 are matters of heartiest congratulation. T. C. C.

THE George Huntington Williams Memorial Lectures, inaugurated in 1897 by Sir Archibald Geike, have been continued this year by Professor W. C. Brögger, of the University of Christiania, who delivered at the Johns Hopkins University two lectures on The Principles of a Genetic Classification of the Igneous Rocks, and five lectures on The Late Geological History of Scandinavia, as shown by changes of level and climate in southern Norway since the close of the glacial epoch. His long and thorough investigation of the igneous rocks of the Christiania region, so varied in character, well preserved and finely exposed, has qualified him to speak with authority upon the subject of their genetic relations, and renders his judgment upon the general problem of the classification of igneous rocks of the first importance. Until the text of these lectures has been published, it will not be in place to discuss the conclusions enunciated by Professor Brögger. The lectures on The Late Geological History of Scandinavia were based upon recent field studies of the glacial phenomena of that region. In addition to their special scientific value, they illustrate the remarkable versatility and energy of Professor Brögger, whose substantial contributions to the paleontology and stratigraphy, the mineralogy and petrology of the Christiania region have already awakened the admiration of his fellow workers.

Professor Brögger also delivered his lectures on the Genetic Classification of Igneous Rocks at the University of Chicago to an appreciative audience of students and geologists, who assembled from various parts of Illinois and from Michigan, Wisconsin, and Minnesota. J. P. I.

Reviews

A Preliminary Report on the Geology of Louisiana. By Gilbert D. Harris, geologist in charge, and A. C. Veatch, assistant geologist. Made under direction of State Experiment Station, Baton Rouge, La. Wm. C. Stubbs, Ph.D., director. [No place or date.]

This report is divided into three sections: I, Historical Review; II, General Geology, and III, Special papers.

In view of the important disagreements between the earlier writers upon Louisiana geology and the authors of this volume the historical review with which it opens is especially important and interesting. The full meaning of this review is only clear after one reads the second part and some of the third part of the volume. The lowest horizons represented are Cretaceous, and the earlier determination of these beds seems to have been based upon the occurrence of a single species, *Exogyra costata*. The present survey has been able to get together a a fairly good representation of the Cretaceous fauna of the state (p. 292–297).

The Mansfield of Hilgard, which was referred by Hopkins to the Jackson (p. 29–35) at the top of the Eocene, turns out to be Lower Lignitic Eocene (pp. 64–73), a horizon not hitherto known to exist in Louisiana. The conclusions reached in regard to the Cretaceous give us a new view of the general geology of the state. The dips and many other facts cited "indicate northeast-southwest local folds parallel to the old shore lines," rather than a northwest-southeast mountain chain (p. 62.) Of the Vicksburgh beds which some of the earlier writers thought they had found between Red River and the Sabine, Professor Harris says "we have found no trace of Vicksburg deposits west of Red River" (p. 90).

A part of the second section of the report is devoted to Economic Geology, and under this head are given valuable data regarding the salt, sulphur, and clay deposits of the state. Among the special reports are several of more than unusual interest. One of these is Mr. Veatch's paper upon "The Shreveport Area." Under this head he

treats at length "the great raft"—a subject of deep interest to geologists (pp. 160–173). He explains its origin, method and rates of growth and decay, and describes the effects of such accumulations and of their removal. He makes some interesting observations upon the lakes of the area, which he classes as: (1) cut-off or horseshoe lakes; (2) lakes of enclosure; and (3) raft lakes. The "raft lakes," it seems, have been attributed to a sinking of the land, but Mr. Veatch thinks they have been formed by the choking up of the former drainage by the accumulation of drift timber in old stream channels (p. 188). The activity of geologic agents in regions of such sluggish drainage has evidently not been realized hitherto, for here in a region at or close to its base level "Lakes have been formed and destroyed; streams have been formed and abandoned; waterfalls produced to destroy themselves; new streams formed out of parts of the beds of old ones and temporary reversals of the drainage systems have been affected" (p. 154). The articles on the Five Islands (pp. 213–262) is by far the most thorough and satisfactory that has yet appeared upon the remarkable salt deposits of Louisiana. The investigation of the clays by Dr. H. Ries is a valuable piece of work done by one of our best authorities on the subject.

Papers of paleontologic interest are given in the third section by Professor Harris upon the Natchitoches area, and upon the Cretaceous and Lower Eocene faunas of Louisiana. These papers are illustrated by seven beautifully prepared plates. Professor Harris also contributes a paper upon meridian lines, and another upon road making. This last subject is entitled to the serious attention of the people of Louisiana. That the geologists are unable to make the most of their time because of the bad roads of the state is to be regretted, and the geologists have our sympathy, but when many of these roads become such quagmires for several months of the year that traffic over them comes to a dead standstill, it is a matter that more or less seriously affects the prosperity and happiness of the entire population.

Arthur Hollick contributes a well illustrated and valuable article upon the Lower Tertiary plants from the northwestern part of the state (pp. 276–288, and 16 plates).

It is pleasant to see that Dr. Stubbs, the director of the State Experiment Stations, under whom the geological survey is being made, appreciates the fitness, ability, and enthusiasm of the men who are doing the work. Indeed it would have been difficult if not impossible to have

found a man better fitted than Professor Harris to take charge of the study of Louisiana geology. The problems of the stratigraphy of the state can be attacked successfully only by a careful study of the fossils. The promptness with which the report has been published is one of its many virtues. The work was begun in November 1898, and Professor Harris' letter of transmission is dated November 1899. Such promptness, however, sometimes has its disadvantages. It is doubtless responsible for several important typographical errors, for the awkward title-page that gives neither date nor place of publication, and for the unfinished condition in which the maps appear. Perhaps it is just as well that the geological map accompanying the report is credited to no one, for to no one is it a credit. With the exception of the maps the volume is well printed and tastefully bound; and the defects we may find in the mechanical part of the work are very small matters compared with the valuable contributions to science contained in the report.

JOHN C. BRANNER.

On the Lower Silurian (Trenton) Fauna of Baffin Land. By CHARLES SCHUCHERT, Proc. U. S. Nat. Mus., Vol. XXII, pp. 143–177, plates XII–XIV.

Any addition to our knowledge of the fossil faunas of the arctic regions is received with special satisfaction by those who are interested in the broader problems of palæontology, in which the facts of geographic distribution are of special moment. The present paper by Mr. Schuchert is one of the most important of such contributions to be found in our literature. It is devoted to the description and discussion of more complete collections of fossils from Sillman's Fossil Mount at the head of Frobisher Bay, than have previously been secured from that locality. Seventy species of fossils are recorded, eighteen being described as new. The fauna shows strong affinities with the Trenton fauna of the United States, especially with the fauna of that age as it is known in Minnesota, a large proportion of the species being common to the two regions.

The Trenton fauna has been recognized at various localities in the arctic regions, the strata containing it always resting unconformably upon the old crystalline rocks. No other Ordovician fauna has been recognized in the whole region save at one locality, on Frobisher Bay,

where a few species indicating a fauna of Utica age have been collected. In general the Trenton beds are followed immediately by strata containing a Silurian (Upper Silurian) fauna of Niagara or Wenlock age.

STUART WELLER.

The Glacial Palagonite-Formation of Iceland. By HELGI PJETURSSON, Cand. Mag. Copenhagen. The Scottish Geographical Magazine, May 1900, Vol. XVI, No. 5.

This appears to be a very important contribution to the history of Pleistocene glaciation. It opens up a new and very promising field, whose data are peculiar because of their association with volcanic phenomena. The author presents in much detail, and with apparent care and discrimination, evidence of glacial formations antedating the so-called "preglacial" lava flows, as well as others interstratified with the lava flows. After twenty-two pages devoted to description of details, illustrated by figures, the author draws the following important conclusions:

I shall not be surprised if this account of the occurrence of glacial deposits and striated rock surfaces in connection with the "palagonite-formation" of Iceland is received with incredulity. For myself, I could hardly believe the evidence when I first encountered it, and tried to explain it in every possible way other than by glacial action. But the glacial origin of the "breccias" could not be gainsaid. Not only did they present a characteristically morainic aspect, but they yielded numerous well striated stones, and in places were found to be resting upon grooved and striated rock surfaces. If the observations I have here recorded be accepted as fairly trustworthy, we cannot avoid the conclusion that glacial deposits, hitherto unrecognized as such, are largely developed in Iceland, or at all events in that part of the island which I have critically examined and referred to in these pages.

As I have had only a glimpse, as it were, into this very promising field of glacial research, I shall not attempt to deal with the glacial succession in Iceland. That must be left for future investigations to determine. Nevertheless there are several conclusions which seem to me obvious enough. Of these the most important, in my opinion, is that which has reference to successive glaciations. The facts advanced show that Iceland has experienced more than one glaciation before the ejection of the doleritic lavas and their subsequent smoothing and grooving by ice. How many separate glaciations the morainic breccias bear witness to is uncertain. But the repeated occurrence of four separate sheets or beds of morainic breccia seems to render it not improbable that there have been just as many separate glaciations during the

accumulation of the so-called palagonite formation. Even if we discard the evidence furnished by the lowest breccias (in which, it will be remembered, that notwithstanding their morainic aspect, no striated stones occurred), we have still the overwhelming evidence of glaciation supplied by the higher morainic breccias. But whether these indurated ground moraines represent three, four, or more glaciations, one or other of them must represent the epoch of maximum glaciation in Europe. The glaciation which left the older system of markings on the dolerite of Stangasfjall is, of course, of later date and may possibly represent the Mecklenburgian stage (Geikie) of northern Europe, and the first postglacial stage of glaciation of the Alps (Penck). It seems more than probable that a change of climate, corresponding to that which in the Alps depressed the snow line about 3000 feet, would bring about the total glaciation of Iceland. Indeed, a much less important change in the climatic conditions would suffice to do this. It is therefore quite possible that the younger system of striae marking the surfaces of the dolerites may be contemporaneous with that readvance of cold conditions which produced the local glaciers of the "Lower Turbarian stage" of Scotland, and those of the "Second postglacial stage" in the Alps.

[The second striated horizon in the moraine of Sudurnes (if it be not a striated pavement) may possibly indicate a third "post-doleritic" glaciation, but until additional evidence be forthcoming, this isolated observation must be left out of consideration.]

So far as I know, all that has been written on the glacial period in Iceland refers to the minor glaciations which supervened after the ejection of the doleritic streams of lava. I say minor glaciations, even although the country appears during those stages to have been totally ice-covered. But the mass of the "palagonite-moraines" is so very much greater than that of the loose accumulations of the later glaciations, that we may reasonably infer that the former are products of much greater ice-sheets. Moreover, the conditions of erosion and accumulation during successive glaciations seem to have differed at the same localities. Further, when we remember that the whole region throughout which the palagonite-formation occurs, has been extensively fractured and consequently has experienced many subsidences — and when we reflect that all these important deformations of the land surface took place subsequent to the accumulation of the uppermost morainic breccias, we are led to suspect that the area over which the older glaciations prevailed may have considerably exceeded that which now exists. Probably conclusive evidence on this point may be obtained by studying the directions of the oldest glacial striae all over the country, and more especially in the north.

It would probably also be of great interest to determine the relations of the Pliocene shell-beds near Húsavík, North Iceland, to the "tuff- and breccia-formation." As I have obtained a grant from the Carlsberg Fund,

Copenhagen, to enable me to continue these investigations, I hope to do so on the lines here indicated.

About 5500 square miles of the total area of Iceland are at present covered with glaciers. The country, therefore, would seem to be in a state of glaciation comparable to that obtaining in Scotland during the fourth glacial epoch as defined by Professor Geikie. Now, if Iceland were to be once more totally glaciated, should we term that final ice-invasion a separate stage of glaciation; or merely an oscillation of the existing glaciers? Would the present inhabited condition of Iceland be considered an interglacial epoch, or merely a stage of temporary glacial retreat?

Such considerations must be kept in view when we are discussing whether the old ground moraines described in this paper have been laid down by an oscillating ice-sheet or during separate glacial epochs.

In Búrfell two bottom-moraines are separated by 150 to 200 feet of basalt, on the striated surface of which the upper moraine reposes. Possibly, however, that basalt does not mark the lowest interglacial horizon.

To the next succeeding interglacial horizon probably belong the conglomerates of Stangarfjall, Bringa, and Hagafjall, which are supposed to be of fluviatile origin. Perhaps also the columnar dolerite of Stangarfjall should be included here. The existence of those conglomerates at such heights and so far inland suggests at least a very considerable oscillation of the ice-sheet. Moreover, we must not forget that the conglomerates in question are buried underneath masses of various volcanic products. [While some of the old gravel beds may well represent old river channels, in other places, as in Hagafjall and Bringa, they had more the character of lacustrine deltas or *cônes de déjection*.]

The next interval between two glaciations is that marked by the so-called "preglacial dolerites" which henceforward cannot claim to be more than interglacial. "At the time these preglacial lava beds were laid down, the country had pretty much the same essential contours that it has at present."[1] But when the uppermost of the "palagonite-moraines" (as in Berghylsfjall and Hagafjall) were laid down, the relief of the country, as we have seen, differed greatly from that which now obtains. In the interval of time that separates these morainic breccias from the eruption of the later lavas, the most radical changes in the contours of the country had been effected, chiefly perhaps by subsidence. The southern lowland of Iceland cannot date farther back than this interglacial epoch.

It is not improbable, indeed, that the essential contour lines or surface features of the whole island, so far as these are older than the later outflows of dolerite, came into existence during this interglacial epoch. We cannot tell at what particular stage the later dolerites were erupted, but we know

[1] Thoroddsen, Explorations etc., p. 35.

that the changes of relief which were effected during the interglacial stage in question were very much greater than those which have taken place since the outflow of the doleritic lavas. And yet these lavas have been glaciated more than once, and we do not know how long they had to wait for their first glaciation.

We seem therefore justified in coming to the conclusion that the two glaciations in question have not been the result of comparatively insignificant oscillations of an ice-sheet, but were really separated by a protracted period. The very occurrence indeed of the interglacial streams of lava over such great areas suffices to show how extensively the ice-sheet melted away. It seems to me highly probable that *all* the so-called "preglacial" lavas are in reality interglacial.

Furthermore, the evidence leads to the inference that the time which has elapsed since the last ice-sheet disappeared from the southern lowland of Iceland is very short as compared to the interglacial epoch that intervened between the first of the glaciations experienced by the dolerites and that next preceding it.

Whether the supposed marine deposit which underlies the glaciated lava on Tungufljót dates back to the closing stages of the interglacial epoch just mentioned, or whether it ought rather to be ascribed to an interval separating the two glaciations which are represented by the two systems of striae upon the surfaces of the later dolerites, future investigations must be left to determine.

No doubt many additional conclusions are suggested by the observations recorded in this paper, but I do not care to consider these at present. As already stated, the chief object of this paper is to point out that there exists in Iceland much hitherto unsuspected evidence of former glacial action. I am indeed sanguine enough to think it not improbable that the records of the glacial period have been more fully preserved here than elsewhere. For it is obvious that the conditions for the protection and preservation of glacial deposits have been with us somewhat exceptional. While in other lands, free from volcanic activity, each succeeding ice-sheet has partly destroyed and partly covered up the deposits of its predecessor, in Iceland the moraines have been greatly sheltered by the products of volcanic eruptions which overlie them. Moreover, crustal movements have contributed directly toward the same end by placing the old moraines beyond the reach, as it were, of succeeding glacial invasions. Not improbably, too, some rocks of the "tuff- and breccia-formation" may be due to the direct interaction of volcanic and glacial forces.

To this is added the discussion of some points of a more special and local nature. It is gratifying to learn that the investigation is likely to be continued. T. C. C.

Fossil Flora of the Lower Coal Measures of Missouri. By DAVID WHITE. U. S. Geological Survey, Monograph XXXVII, 468 pp., 1900.

The coal floras are always of great interest. The present contribution is the most important that the central-West has seen since the appearance of Lesquereux's classic work of a quarter of a century ago. The title of the volume does not, however, express the real scope of the work. Most of the forms come from a single locality, near Clinton, in Henry county, Missouri, and from a single horizon — the Jordan coal. The latter is the lowest workable coal seam in the district and is only about 100 feet from the base of the Coal Measures.

While the greater part of the monograph is taken up with the minute descriptions of species, and discussions of the biological relationships of these, the chief interest to the stratigraphical geologist is centered in the data furnished for broad correlations.

Regarding the probable stage of the lower coals of Clinton in eastern sections, Mr. White says: "If we take Henry county, from which most of our evidence, both stratigraphic and paleontologic is drawn, as the stratigraphic type of the base of the Coal Measures of the state, and assume that the conditions are constant along the margin of the coal field in other counties, the evidence of the fossil plants, so far as they are now obtainable, appears to indicate the deposition of the lowest coals in the state at a time subsequent to the formation of the lower coals of the Lower Coal Measures of the eastern regions, including the Morris coal of Illinois, the Brookville and probably the Clarion coal of Ohio and Pennsylvania, yet perhaps earlier than the formation of the Darlington or upper Kittanning coals of the two states last named.

"The study of the distribution of the Henry county flora in this field shows its closest relations in coals D and E, locally known as the 'Marcy' and the 'Big' or Pittston coals. But in view of the fact that the E coal of the Pittston and Wilkesbarre regions seems to carry many types of a more modern cast, it is not likely that the Missouri stage is so high in the series as that coal. In the plants of the D coal, not only are a large part of the species identical with those from Missouri, but the flora as a whole is of a similar type. Compared, however, with the somewhat equivocal combined flora reported from the C coal, the material from the Mississippi valley appears on the whole fully as recent, while lacking many of the older types found at several

of the mines correlated by stratigraphy with that coal. Hence I am inclined to regard the plants from Henry county, Missouri, as more clearly contemporaneous with those in the roof of the D or 'Marcy' coal in the northern anthracite field, though they are possibly as old as the C coal."

The reference to the unconformity at the base of the Missouri Coal Measures is full of significance. "The transgression of the water level during the early Mesocarboniferous time has already been discussed by Broadhead, Winslow, and Keyes, the state geologists. The evidence of the fossil plants not only corroborates their views in general, but it also fixes the time of the encroachment of the sea on the old coast in the region of Clinton. The paleobotanic criteria indicates that the minimum time represented by the unconformity between Jordan or Owen coal and the subjacent Eocarboniferous terrane is measured by the period required for the deposition of the Pottsville and the Clarion group of the Lower Productive Coal Measures, a series of rocks reaching a thickness of over 1200 feet in portions of the anthracite regions, and exceeding 2400 feet in southern West Virginia."

The depositional equivalent of the unconformity at the base of the Missouri Coal Measures is even more important than Mr. White has indicated. As quite recently stated there is farther south in Arkansas, a sequence of Coal Measures beneath the basal horizon of the Des Moines and Missourian series combined. In reality the geological position of the Lower Coal Measures (Des Moines series) of Missouri appears to be well up in the median part of the Middle Carboniferous instead of at the base, as generally considered. Only in Missouri, about one half of the Middle Carboniferous is unrepresented by strata. This lacking series may be represented in Arkansas by upwards of 12,000 feet of sediments!

Attention is called in the monograph to some of the obstacles to accuracy in correlation and especially to the lack of standard paleobotanic sections. If ever there were opportunity of establishing a standard section of this kind it is in the Trans-Mississippian coal field. Plant remains occurs abundantly in many localities and at many horizons extending from the very base of Des Moines, up through the Missourian, into the so-called Permian. The monograph on the Missouri fossil floras considers chiefly one locality and one horizon. In Missouri alone there are no less than 150 known localities and 30 horizons for coal plants. In Iowa there are nearly as many more.

Kansas likewise offers an equally inviting field. If a single location yields up such prodigious possibilities as Mr. White has demonstrated what may we not expect from the rest of the vast field!

C. R. KEYES.

The Devonian "Lamprey," Palaeospondylus Gunni, Traquair. By BASHFORD DEAN (Mem. N. Y. Acad. Sci., Vol. II, Part I), 1899.

This elaborate memoir of thirty quarto pages and a plate drawn and lithographed by the author himself represent a vast amount of labor expended on minute, poorly preserved, and what would seem at first sight insignificant objects, found in the Caithness flags of Scotland. The fossil remains of *Palaeospondylus* are very unsatisfactory for study, and but for the peculiar interest attaching to them as supposed representatives of Palaeozoic Lampreys, they would hardly command attention. But zoölogists have been eagerly awaiting whatever enlightenment palaeontology might offer on the relations and descent of the Cyclostomes, and when Dr. R. H. Traquair announced his discovery of *Palaeospondylus* in 1890, it was hailed with delight as a definite clew to Cyclostome genealogy.

Dr. Dean observes: "Zoölogists were by no means unwilling to accept *Palaeospondylus* as a fossil lamprey; and they even found it a difficult matter to avoid going out in the road to give it a charitable reception. The fossil came, was seen, and was currently accepted. But time has gone by and suspicion come, and the thought is by no means comforting that the wrong prodigal may have been welcomed. Is *Palaeospondylus*, then, a veritable Cyclostome, or is it at least a provisional one?" Dr. Dean's purpose in investigating this question is a critical one, and he states that he has "attempted to analyze the results of preceding writers, to contribute some further data to our knowledge of the structure of this form, and to endeavor finally to determine what conclusions are justified in assigning a place to this fossil. After accomplishing all this in very satisfactory fashion, the author takes up the classification of fishlike vertebrates in general and introduces some novel changes, which will be referred to presently.

Dr. Dean's conclusion as to the Marsipobranch nature of *Palaeospondylus* takes the form of a more emphatic denial than ever (see his previous paper in *Proc. Zoöl. Soc.*, April 1898) that it can be regarded

even provisionally as a fossil lamprey. Dr. Traquair's objection that if *Palaeospondylus* be not a Marsipobranch it is impossible to refer it to any other existing group of vertebrates, Dr. Dean disposes of by boldly placing it in a new class by itself, elevating the order Cycliae, which Gill created for it, to that rank. Such a course may strike one as rather startling, perhaps, but it is certainly effective. An alternative proposition which Dr. Dean suggests may be more acceptable to some ichthyologists "is to place it with *Coccosteus* as doubtfully its larval form." Although there is considerable reason for regarding the variations in this small form as the early stages of some larger chordate, yet there is no direct proof that the adult form was an Arthrodire; hence this association would have to be at best only provisional, and, in the author's opinion, is inexpedient. As to the relations of newly exalted Cycliae to other classes, we are left as much in the dark as ever. Some very excellent figures of the fossil forms are given, together with a diagrammatic restoration.

Very interesting, indeed, are the author's views on the systematic arrangement of the early forms of fishlike vertebrates and fishes proper, with which the paper concludes. Amongst the latter the Chimaeroids are reduced again to the rank of an order instead of a subclass, principally as the result of Dr. Dean's recent embryological investigations, and the Dipnoi are reduced from class rank (Parker) to that of a subclass. *Acanthodes* and *Cladoselache* are grouped together under the primitive Elasmobranch order Pleuropterygii.

Turning now to the most primitive of all chordates, Dr. Dean elevates the Ostracoderms and Arthrodires each to the rank of an independent class, the former with its customary triple subdivision, but the latter separated into two new divisions, Arthrodira proper and Anarthrodira, which rank as subclasses. On the ground of their lacking a mandibular arch and paired limbs, the Ostracoderms were denied by Cope, and following him by Smith Woodward, and others, to be fishes at all, but organisms far removed from the latter, called "Agnatha." The origin and relations of the Ostracoderms are at present among the most important and fascinating questions of palaeichthyology. Dr. Traquair, in an extremely valuable memoir of last December[1] refuses to believe that these forms are Agnatha, declaring Cope's view to rest entirely on negative evidence, and preferring to look upon the lowest

[1] Report on Silurian Fishes (Trans. Roy. Soc., Edinburgh, Vol. XXXIX, Pt. III), 1899.

Ostracoderms "as having definitely split off from the Elasmobranchs, from which they doubtless originally came." Dean believes in a wider separation, however, from the groups represented by recent forms; but regarding the differences between Ostracoderms and Arthrodires, he makes the following significant remark: "A renewed examination of the subject has caused me to incline strongly to the belief that Pterichthys and Coccosteans are not as widely separated in phylogeny as Smith Woodward, for example, has maintained. But as far as present evidence goes, they appear to me certainly as distinct as fishes are from amphibia, or as reptiles are from birds or from mammals" (p. 24). The reference to Smith Woodward bears, of course, on the recognition of Arthrodires by that author as an order of Dipnoi.

Whatever may be thought of the class Cycliae, there is no question but that Dr. Dean has scored an advance by elevating the Ostracoderms and Arthrodires to a higher rank and placing them in close proximity to one another. A separation of the two classes is rendered necessary of course, thus prohibiting the revival of McCoy's "Placodermata," by the absence of "jaws," endoskeletal structures, and paired limbs in the first-named group. Nevertheless the two classes have a number of points in common, and should we be led to infer with Traquair an Elasmobranch derivation of the Ostracoderms, it would be natural to trace Arthrodires to the same source. Whether there were really "Agnatha," and how far the archaic fishlike vertebrates were removed from the groups represented by living forms, must be left for future study to decide. Or possibly we may never have the solution of these perplexing problems.

In one minor point only the reviewer finds himself in disagreement with Dr. Dean, and this relates to the subdivision of Arthrodires (or "Arthrognaths," to use his new term) into Arthrodira proper and Anarthrodira. The latter includes *Macropetalichthys*, *Trachosteus*, *Mylostoma*, and certain transitional forms which the author promises shortly to describe. When the cranial and body armoring of *Trachosteus* and *Mylostoma* are made known, their position may become evident. At present we are acquainted only with the cranial osteology of *Macropetalichthys*, and this is so far different from that of typical Arthrodires that in the reviewer's opinion it cannot be retained in the same class. As typical of an independent family, it had best be removed with the Asterosteidae to a position amongst the Ostracoderms, as we certainly do not wish to make of it an independent class. The comparisons between

this form and the cranial and dorsal shields of Arthrodires indicated by Cope and the reviewer a few years ago were based upon a misconception of the septum dividing off the so-called "nuchal plate;" but in reality no homology exists between arrangement of cranial plates or the sensory canal system of this form and those of Arthrodires. No plates corresponding to the dorsal or ventral armoring of *Coccosteus*, etc., are known, nor is there any evidence of a lower jaw, of paired fins, neural or haemal arches, nor any form of dental plates attached to the roof of the mouth. Finally, the bone-structure is perceptibly different from that of typical Arthrodires, and the under side of the head is unparalleled in the latter group. This form is certainly worthy of careful reinvestigation.

The whole matter of Dr. Dean's Anarthrodira, is, however, of subordinate importance as compared with his main theme, which is admirably treated; and palaeontologists will be sure to appreciate his clear exposition of the same, supplemented as it is by a complete bibliography and expertly drawn figures.

C. R. EASTMAN.

Some High Levels in the Postglacial Development of the Finger Lakes of New York. By THOMAS L. WATSON. With 30 figures and 3 maps. The figures being mostly full page half-tones, maps, and diagrams. Appendix B. Report of the Director of the New York State Museum, 1899.

Dr. Watson presents in a very clear and interesting manner the results of the earlier works of other investigators and of his own extended observations on the high level terraces and water marks in the Finger Lakes region. He finds that at the time of maximum advance of the "ice of the second glacial period" (by which he probably means the early or late Wisconsin of some writers) the ice front extended to and beyond the present divide which separates the waters draining northward into the St. Lawrence and those of the Chemung-Susquehanna draining to the southward. The preglacial valleys now occupied by the Finger Lakes were entirely overridden by the ice but were not completely filled with the glacial débris, so that as the ice front began to retreat and had drawn back to a position north of the divide there was formed, in the valleys, numerous local glacial lakes which drained southward through several channel ways. These channel

ways were at different levels for the different lakes and as the ice front drew back to the northeast, the several local lakes coalesced into fewer larger bodies of water and the higher outlets were abandoned in succession until finally there was but one body of water, Lake Newberry, with a single outlet to the southward. This outlet was finally abandoned when the waters of Lake Newberry fell to the level of and coalesced with those of Lake Warren. At last the opening of the St. Lawrence and the lowering of the Lake Iroquois left the waters of the present Finger Lakes in the old valleys, held back by drift barriers. The evidence for this sequence of events, which the author traces with much detail, is found largely in the high level delta deposits made by the tributary streams in the temporary glacial lakes at the levels of the southern outlets which mark the successive stages of water levels. Dr. Watson's map of the temporary, local, glacial lakes of the Finger Lakes region suggests that under similar relations of ice front to topographic form, such as undoubtedly prevailed farther westward in New York and through northern Ohio, the results of glacial action would be much the same and that if we are to arrive at a correct interpretation of the sequence of events during the Pleistocene it will be through the detailed study of many limited areas in the careful painstaking manner shown by the work of Dr. Watson. Such work cannot be too highly commended. W. G. T.

Twentieth Annual Report of the U. S. Geological Survey, Mineral Resources of the United States, 1898. Washington, D. C. 616 and 804 pages.

The annual report on the mineral resources for 1898 like its predecessors contains much valuable statistical and descriptive matter on the different mineral products of the United States. The data in the present report have been brought up to the close of 1898 and, as has been customary since 1894, when this publication was first made a part of the annual report, along with the statistical matter there is included valuable information on the industrial uses, improvements on ore reduction, new developments, distribution of ores, chemical analyses, and other data concerning the different products. The statistics on some of the products are given in great detail, thus nearly one hundred pages are devoted to a discussion of the iron ores and the American and foreign iron trade, which is not an undue proportion of space

when we consider that the value of iron for 1898 was 116.5 millions of dollars against 227 millions for all the other metallic products. Likewise 314 pages are given to the coal and coke industries but the value of the coal alone is 208 million dollars against 145 millions for all other non-metallic products. The total value of all the mineral products for 1898 is $697,820,720 which is an increase over the preceding year of $66,966,791 or 10.62 per cent.

Some of the more important special topics discussed are (1) the history of gold mining and metallurgy in the southern states by H. B. C. Nitze; (2) the characteristics, uses and domestic and foreign production of manganese ores by John Birkinbine; (3) the slate belt of Eastern New York and Western Vermont by T. Nelson Dale; (4) more than 100 pages of analyses and tests of building stones collected from various sources by Wm. C. Day and classified and arranged by states; (5) a brief reconnaissance of the Tennesse phosphate fields by C. Willard Hayes; (6) the mica deposits in the United States by J. A. Holmes; and (7) the mineral resources of Porto Rico by Robert T. Hill, and H. B. C. Nitze.

T. C. H.

Les Charbons Britanniques et Leur Épuisement. By Ed. Lozé. Two volumes. Paris, 1900.

This work is an exhaustive treatise on British coals, comprising a discussion of their history, exploitation, production, consumption, geological occurrence, value, qualities, classification, utilities, and exportation. The work as whole is divided into four parts. Part one presents a general discussion of the geography and inhabitants of Great Britain and Ireland; their social, political, and economic conditions; the influence of the coal industry on economics, navigation, naval power, and the national debt; the geology of the British Isles; the history of coal production and the statistics bearing on its production and consumption.

Part two furnishes a description of the coal beds of the United Kingdom and discusses their importance and productiveness. This is followed by a series of chapters on the industrial and commercial geography of the Islands, constituting the third part of the work. The fourth part treats of the productiveness of the coal mines, and the probable time of depletion.

It is thought probable that coal was first used in Britain by the early Bretons, but direct evidence of it is wanting. However, it is known to have been used by the Roman invaders, as cinders and coal ashes have been found in the ruins of the Roman houses. Not much is known of the coal industry from the time of the Roman invasion until the beginning of the thirteenth century when it is referred to in certain land grants. The first mines were located in the vicinity of Newcastle. By the year 1379 coal had become of sufficient importance to make it an object of impost. By the beginning of the sixteenth century the production had reached an avefage of a million tons per year, and the total production from that date to 1866 is estimated to be 850 million tons.

The principal coal beds of the United Kingdom occur in the Coal Measures or upper part of the Carboniferous series. According to Hull the Lower Carboniferous has a threefold division: (1) the lower schist group, (2) the Mountain limestone, and (3) the Yoredale group. The Upper Carboniferous is divided into (1) the Millstone grit, (2) the lower Coal Measures, (3) the middle Coal Measures, and (4) the upper Coal Measures. The last three divisions contain the productive coal beds. The work is accompanied by maps locating accurately the known coal areas and giving the probable extent of the undetermined ones.

The coals of Britain are classed under the heads of:

1. Lignites, containing 67 per cent. of carbon and 26 per cent. of oxygen.
2. Bituminous coal, containing 75 to 90 per cent. of carbon and 6 to 19 per cent. of oxygen.
3. Steam coal, a sort of semi-anthracite.
4. Cannel coal, containing 40 per cent. of volatile matter and being rich in hydrogen.
5. Anthracite coal, containing 93 to 95 per cent. of carbon and 3 per cent. of oxygen with 2 to 4 per cent. of hydrogen.

The total exportation of coal from the British Isles in 1898 was 35 million tons, which was a decrease over the preceding year of about 300,000 tons. The importation of coal for 1897 was only 9454 tons. The amount of coal consumed per capita in 1898 was 3.867 tons.

The author discusses the estimate made by the Commission of 1870, that the coal resources of the United Kingdom are 80 billion tons, and that at the present rate of depletion (2 million tons per year)

the total exhaustion will take place in four hundred years; and arrives at the conclusion that the time may be even less than that given by the Commission. That the day of complete depletion will come, the author is assured, and when it does come "the historian of a powerful empire will terminate, very probably, the narrative of a remarkable epoch with these words, *finis Britannae*." W. N. LOGAN.

Cape Nome Gold Region. By FRANK C. SCHRADER and ALFRED H. BROOKS. United States Geological Survey, Special Report, 56 pp. Washington, 1900.

The Cape Nome gold field which has recently occasioned so much excitement is of special interest geologically on account of being the most noteworthy modern beach placers known. The type of ore deposits to which these Alaskan beds belong has long been recognized, but no bodies of this kind have ever proved so rich. Ancient deposits of the same origin are not unknown. Such are the Witwatersrand blanket of the Transvaal and the Napoleon Creek conglomerate in Alaska.

The Nome district is on the southern shore of the Seward peninsula in a little known part of northwestern Alaska. "The beach rises gradually to a sharply cut bench, a hundred to two hundred yards from the surf. From the edge of this terrace, which is about twenty feet high, the moss-covered tundra extends inland, rising uniformly about two hundred feet in four or five miles, when it merges into the highland belt."

The bed-rock of the region is composed of limestones and phyllites or mica schists interbedded, with some gneiss. Igneous rock is of rare occurrence. Over this foundation lie the unconsolidated gravels with gold-bearing zones. The authors emphasize the fact that during the deposition of the gravels and sands the conditions were not materially different from those of today, except that the land stood at a lower elevation relatively to the sea. "There is no evidence whatever of glacial action in the region, and the popular idea that the gravels were brought to their present position by ice action is entirely erroneous."

The gold-bearing deposits are grouped into gulch-placers, bar-placers, beach-placers, tundra-placers, and bench-placers. The gulch and beach placers are the most productive. During the past year (1899) the production was three million dollars.

The gold is usually rounded and often smoothly polished. It is not evenly distributed through the gravels but gathered in zones. In

washing the pay-streaks the heavy minerals garnet and magnetite are concentrated along with the gold. The first forms "ruby sand" and the latter "black sand."

Good prospects for gold occur in many other places in the Seaward peninsula. "The geographic portions of some of the different localities suggest that they may belong to the same gold belt. The facts known to us, however, are not sufficient to prove this; and it must simply be regarded as a working hypothesis. Should subsequent development and investigation show that the gold of all of these districts of Seward peninsula is derived from the same series of rocks, this gold-mining region will embrace an area of at least 5000 to 6000 square miles. If this proves to be the case, it does not by any means follow that the entire belt will contain workable gold deposits. We should rather expect to find the gold confined to certain zones within the belt."

The report is accompanied by a number of excellent views of the region. This preliminary report gives us a good idea of just what the visitors and prospectors may expect when they reach the Cape Nome region. Scientists will await the appearance of the final report with interest.

C. R. KEYES.

Syllabus of Economic Geology. By JOHN C. BRANNER, Ph.D., and JOHN F. NEWSOM, A.M., Second Edition, 1900, pp. 368. Plates and Diagrams.

This volume is a syllabus of a course of lectures on economic geology given by the authors at Leland Stanford Junior University. It is intended primarily for the student, but will also be found a most valuable guide to anyone interested in the various branches of economic geology. It begins with a general list of the more important works on economic geology, and of the periodicals relating to this subject. After this are a few introductory remarks on geology in its relation to various economic subjects, including mining, agriculture, forestry, manufacturing, industries, art, roads, railways, migration, etc., followed by a brief synopsis of geological sections, maps, surveys, etc., from an economic standpoint; a summary of economic geological products and their various classifications as proposed by different authors; rock-cavities; the formation of ore bodies; and the features of ore deposits. This general part of the subject takes up the first fifty pages, and most of the rest of the volume treats of different kinds of ore deposits and

other deposits of economic value, including iron, chromium, manganese, copper, tin, cobalt and nickel, zinc, lead, silver, gold, platinum group, tungsten, molybdenum, antimony, bismuth, cadmium, arsenic, mercury, precious stones, coal, graphite, petroleum, natural gas, ozokerite, asphalt, salt, soda, borax, niter, soda niter, barytes, sulphur, iron pyrites, feldspar, fluorite, mineral pigments, abrasives, marble, limestones other than marble, building stones in general, kaolin, clay, bauxite, aluminum, glass sand, refractory materials, natural fertilizers, monazite, road materials, soils and water. Under each of these headings is given a brief account of the chemical and mineralogical character of the material under discussion, its mode of occurrence, its distribution, and other technical or commercial data of interest, together with a list of the more important literature on the subject. The volume closes with a few very pertinent remarks and suggestions on the subject of reports on mining properties, and with a list of references to works on mining law.

The lists of literature given in the volume contain the more important publications on the different subjects treated, and though, as the authors themselves say, they have not attempted to make the bibliography complete, yet the references which they have given are all useful and will be found to be a ready guide to those who wish to follow up the subject further. For the student, this system is especially useful, as he gets in the syllabus only references to the most important literature, and is not encumbered with what is not immediately necessary for his purposes; at the same time he has the means of finding any other literature that may exist on the subject. A very useful feature of the volume are the blank pages which alternate with the pages of printed matter, thus giving means of inserting further references to literature or making short notes, etc.

The volume contains 141 illustrations including geological sections, sections of ore bodies and of mines, statistical tables, etc., all of which add greatly to the usefulness of the work as they make it possible in a condensed form to understand clearly the various subjects discussed.

The volume relates mostly to the economic geology of the United States, but that of foreign countries is occasionally mentioned. It covers a wide field in a form which though condensed is sufficiently full to answer all the purposes for which it is intended. It is a most valuable work, and the thanks of all interested in economic geology are due to the authors who have prepared it. R. A. F. P., Jr.

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